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RESPONSE TO UNESCO RECONSTRUCTION APPEAL

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DESIGN

DATA BOOK for CIVIL ENGINEERS

By ELWYN E. SEELYE

VOLUME ONE DESIGN. 417 pages. Illustrated. 9⅜ by 11¾. Cloth.

VOLUME TWO SPECIFICATIONS AND COSTS. 325 pages. Illustrated. 9⅜ by 11¾.

VOLUME THREE FIELD PRACTICE. 306 pages. Illustrated. 5 by 8¼. Cloth.

DATA BOOK FOR CIVIL ENGINEERS

DESIGN

ELWYN E. SEELYE

New York—JOHN WILEY AND SONS, INC.
London—CHAPMAN AND HALL, LIMITED

SEVENTH PRINTING OCTOBER, 1950

PRINTED IN THE UNITED STATES OF AMERICA

FOREWORD

The author of this volume has made an important contribution to his profession by making available design data developed in the course of his experience, covering a period of 35 years, supplemented by similar data drawn from the latest publications of outstanding authorities.

The compilation is of an inclusive character and will be useful to all workers in the field of civil engineering, not only as a reference manual but also as offering basic data concerning current practice which could otherwise be obtained only after extensive research. This volume, which will be supplemented by others covering specifications, costs, and field practice, will fill a long felt want.

The book contains many original plates of unusual interest, such as those showing methods for rapidly figuring combined flexure and axial stress in columns, those showing the development of highway transition curves, and those showing safe loads on manhole and catch basin covers and on sewer pipes. Explanations and derivations have been largely eliminated, as the notes on the plates give the necessary explanation and guidance. The volume may be described as unique in engineering literature, for it combines maximum data with a minumum explanation. The author is to be congratulated on the clarity of presentation, which he has achieved by full use of illustrative details and examples.

ARTHUR S. TUTTLE

PREFACE

Most civil engineers collect data which are particularly pertinent to their work. Indeed, the engineer's efficiency depends largely on the quality of the data with which he equips himself.

The growth of technical codes of practice promulgated by technical societies, trade associations, and government bureaus, while advancing the science of civil engineering, has tended to render the practice of engineering more dependent on data than formerly. This has created an unhealthy degree of specialization. For instance, a structural engineer is likely to balk at designing a drain because he does not have the data on runoff and flow in pipes readily available.

The purposes of this volume are:

To make readily available in one place effective data in each main field of civil engineering — structures, sanitation, water supply, drainage, roads, airfields, dams, docks, bridges, and soils.

To make this book complete in itself so that a civil engineer isolated from other reference books and technical data could function.

To furnish data which will eliminate tedious office computing and thus minimize errors made in such computations.

To aid the engineer in attaining results in accordance with the best engineering practice by making available data based on such practice.

To expand the field of activity of the specialized engineer by providing him with handy data in fields allied to his specialty.

In general, desirable engineering information embraces model specifications, and data on design, cost, and field practice. This volume embraces the design data and has been arranged to be as nearly self-indexed as possible. A field manual and a book containing cost data and model specifications will be issued as subsequent volumes.

This book has been written with the view that the practicing engineer, who must produce working designs, needs data carried to final conclusions, even though much technical writing dodges these conclusions on account of the common inhibition among engineers against expressing themselves definitely and without reservations. The directness of the data in this book, which have been presented without these usual reservations, render it incumbent upon the writer to warn that data cannot be considered a substitute for intelligent judgment based on practice and consideration of all factors and phases of the specific problem at hand. For this reason, collateral reading is encouraged by abundant references, but in general no collateral reading is required to arrive at a direct solution of an engineering problem.

ELWYN E. SEELYE

January 30, 1945

ACKNOWLEDGMENTS

Dr. Arthur S. Tuttle, for his help and advice and for making available to the author his wide contacts for the collection of information.

Dean S. C. Hollister, of the College of Engineering, Cornell University, who has given the author advice and encouragement, particularly in regard to the general scope of the book.

Mr. Elson T. Killam, who has given extensive advice and assistance in preparing chapters on sanitation and water supply.

Mr. Clinton L. Bogert, who has also assisted on sanitation and water supply.

Gilbert D. Fish, who has aided in the preparation of data on arc-welding.

Col. F. W. Scheidenhelm, who has given the author general advice on dams.

Col. Marcel Garsaud, who has given us constructive criticism on the dock section.

Mr. Shortridge Hardesty, who has given the author advice in preparing the data on bridges.

Mr. Bedrich Fruhauf, who has assisted on soil mechanics.

Professor Hamilton Gray, of New York University, who has given the author advice on soils.

Mr. C. Joseph Klueh, of the New York Central Railroad, who has given advice on railroads.

Mr. Lazarus White, who has given advice on dams and foundations.

Mr. Harry T. Immerman, of Spencer, White & Prentis, for advice on foundations.

Mr. E. P. Albright, of Underpinning and Foundation Co., for his advice on foundations.

Mr. F. Ellwood Allen, for his advice on athletic fields.

Mr. George Seybolt, of Electric Bond and Share Co., for his advice on transmission towers.

Mr. Robert C. Dennett, Assistant Chief Engineer of the National Board of Fire Underwriters, for his advice on fire flow tests.

Mr. Albert E. Cummings, of Raymond Concrete Pile Co., for advice on piles.

Mr. Isaac J. Stander, for advice on docks.

Mr. Walter D. Binger, Commissioner of Borough Works, for making available New York City standards.

Mr. Robert E. Horton, for advice on drainage.

Mr. Richard M. Hodges, for advice on highway bridges.

Mr. Fred J. Biele, for advice on incinerators.

Others who have given advice or criticism are:

Col. Carlton S. Proctor.

Mr. Prevost Hubbard and Mr. Bernard E. Gray, of The Asphalt Institute.

Mr. Allan S. Platt, of Structural Clay Products Institute.

Mr. James C. Harding, Commissioner of Public Works, Westchester County, New York.
Mr. T. W. Pinard, Engineer of Bridges and Buildings, Pennsylvania Railroad.
Mr. William S. Elliott, Chief of the Materials Section, Department of Public Works, City of New York.
Mr. George Pistor, Vice-President of Bethlehem Steel Co.
Mr. Wilton Bentley, Vice-President of K. W. Battery Company.
Mr. S. Neatwait, Chief Engineer, Republic Fireproofing Co.
Mr. J. F. Dealy, Vice President, MacArthur Concrete Pile Corporation.
Mr. E. M. Fleming, District Manager, Portland Cement Association.
Mr. Bertrand H. Wait, President, The Wait Associates, Inc.
Mr. L. J. Markwadt, of Forest Products Laboratory.
Mr. Edward A. Robinson, of Colonial Sand and Gravel Co.
Professor Henry N. Ogden, of Cornell University.
Mr. Ralph H. Mann, of American Wood-Preservers' Association.
Mr. Frank H. Alcott, of National Lumber Manufacturers Association.
Mr. T. R. Higgins, Director of Engineering, American Institute of Steel Construction, Inc.
Mr. Orvil S. Tuttle, Chief Engineer, U. S. Plywood Corporation.
Mr. Elliott Haller, of Haller Engineering Associates, Inc.
Major Rolf Eliassen.
Mr. W. A. Darby and Mr. R. S. Rankin, of the Dorr Co., Inc.
The late Mr. A. M. Brosius.

The author wishes to make special mention of the self-sacrificing support received from the following members of his organization:

Mr. A. L. Stevenson, who has provided the initiative for a large part of the structural section.
Messrs. V. J. Pacello and C. Mortimer Throop, for the structural section.
Mr. J. U. Wiesendanger, for general editing and for the sections on airports and railroads.
Mr. E. G. Whitten, for sections on roads, airports, and soils.
Ensign Harold Hayward and Lt. Jack L. Staunton, for sections on sewage treatment and water supply.
Mr. A. F. Stine, for the section on drainage.
Col. Burnside R. Value, Mr. Rolf Sahlberg, Mr. Laurence Vought, Mr. Julius G. Lenart, Mr. Karl Bloch, Mr. E. R. Kroyer, Mr. C. H. Hamilton, Mr. A. H. Jorgensen, and Mr. Kenneth Whitney, for general assistance.

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STRUCTURAL - UNIT STRESSES

TABLE A - ALLOWABLE WORKING STRESSES IN CONCRETE (BASED ON ULTIMATE STRENGTH = f'_c.)

DESCRIPTION	ALLOWABLE WORKING STRESSES N.Y.C. CODE	A.C.I. CODE	
FLEXURE:			
Extreme fiber stress in compression.	$0.40 f'_c$	$0.45 f'_c$	
Extreme fiber stress in compression adjacent to supports of continuous supports, of cont. or fixed beams, or slabs, or of rigid frames.	$0.45 f'_c$	$0.45 f'_c$	
Tension in plain concrete footings.	$0.03 f'_c$*	$0.03 f'_c$	
SHEAR:			
Beams with no web reinforcement and without special anchorage of longitudinal steel.	$0.02 f'_c$	$0.02 f'_c$	
Beams with no web reinforcement, but with special anchorage of longitudinal steel, see Page 1-25.	$0.03 f'_c$	$0.03 f'_c$	
Beams with properly designed web reinforcement but without special anchorage of longitudinal steel, see Page 1-38.	$0.06 f'_c$	$0.06 f'_c$	
Beams with properly designed web reinforcement and with special anchorage of longitudinal steel, see Pages 1-25 and 1-38.	$0.09 f'_c$	$0.12 f'_c$	
Flat slabs at distance "d"[3] from edge of column cap or drop panel.	$0.03 f'_c$	$0.03 f'_c$	
(a) When at least 50% of total neg. reinf. passes over the column cap.	$0.03 f'_c$	$0.03 f'_c$	
(b) When 25% or less of total neg. reinf. passes over the column cap.	$0.025 f'_c$	$0.025 f'_c$	
(c) For intermediate percentages use intermediate values.			
Footings where longitudinal bars are without special anchorage.	$0.02 f'_c$		
Footings where longitudinal bars have special anchorage.	$0.03 f'_c$	$0.03 f'_c$[2]	
[2] Not to exceed 75 lbs. per sq. in. [3] "d" being the distance equivalent to the thickness of slab without drop panels minus 1½", or the thickness of flat slab through the drop panels (where such are used) minus 1½", or thickness of flat slab (with drop panels) at points outside the drop panel minus 1½".			
BOND[6]**:**			
Beams, slabs & one-way footings: (a) Plain bars or struct. shapes.	$0.04 f'_c$	$0.04 f'_c$[4]	
(b) Deformed bars.	$0.05 f'_c$	$0.05 f'_c$[5]	
In two-way footings: (a) Plain bars or structural shapes.	$0.03 f'_c$	$0.045 f'_c$[4-7]	
(b) Deformed bars.	$0.0375 f'_c$	$0.056 f'_c$[5-7]	
[4] Not to exceed 160 lbs. per sq. in. [5] Not to exceed 200 lbs. per sq. in. [6] Where special anchorage is provided one and one-half times these values may be used. A.C.I. Code limits values to 200 lbs. per sq. in. for plain bars and 250 lbs. per sq. in. for deformed bars. [7] Values for two-way footings include allowance for special anchor.			
BEARING:			
Direct bearing on full area.	$0.25 f'_c$	$0.25 f'_c$	
Direct bearing on one-third full area or less.	$0.375 f'_c$	$0.375 f'_c$	
The allowable bearing stress on an area greater than one-third but less than the full area shall be interpolated.			
AXIAL COMPRESSION:			
In columns with lateral ties.	$0.25 f'_c$		
In pedestals.	$0.25 f'_c$	$0.25 f'_c$	

$$n = \frac{30{,}000}{f'_c}$$

TABLE B - REINFORCEMENT (Values in lbs. per sq. in.).

Structural grade billet steel. - Tension = 18,000	Web reinforcement Tension = 16,000
Intermediate grade billet steel. " = 20,000	Cold drawn steel wire " = 20,000
Rail steel, straight or machine bent " = 20,000	

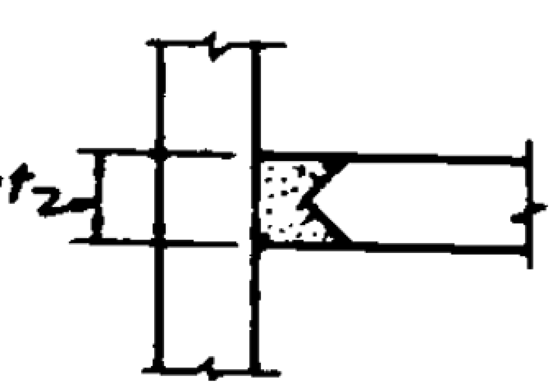
*For N.Y. City code requirements add 4" to depth of footing (see Page 2-51).

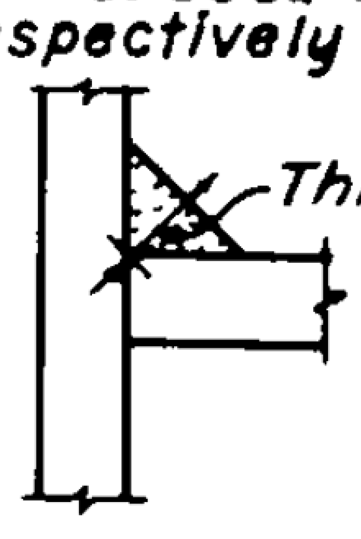
STRUCTURAL-UNIT STRESSES

TABLE A - ALLOWABLE WORKING STRESSES IN STEEL (IN LBS. PER SQ. INCH).

STRUCTURAL AND RIVET STEEL	A. I. S. C.	N. Y. CITY	OTHER LOCALITIES
TENSION			
Rolled steel, net section	20,000	18,000	
Rivets, on area based on nominal diameter	15,000	13,500	
Bolts and other threaded parts on nominal area at root of thread	12,000		
COMPRESSION			
Columns, gross section, axially loaded with $l/r < 120$	$17{,}000-0.485\,l^2/r^2$		
" " " " " " $l/r > 120$	$\frac{18{,}000}{1+l^2/18{,}000r^2}$		
Plate girder stiffeners, gross section	20,000		
Webs of rolled section at toe of fillet.	24,000		
Rolled steel, on short lengths or where lateral deflection is prevented		18,000	
Columns, gross section		$\frac{18{,}000}{1+l^2/18{,}000r^2}$	
with a maximum of		15,000	
l/r not to exceed 120 for main compression members			
l/r not to exceed 200 for bracing and other secondary members			
FLEXURE (BENDING)			
Tension on extreme fibers (Use gross area if holes for rivets do not exceed 15% of gross flange area. Use net area if holes are for bolts, pins or c'fs'k rivets).	20,000		
Tension on extreme fibers of rolled sections, plate girders and built-up members (net area)		18,000	
Compression on extreme fibers of rolled sections, plate girders and built-up members for values of l/b not greater than 40	$\frac{22{,}500}{1+l^2/1800b^2}$	$\frac{20{,}000}{1+l^2/2000b}$	
with a maximum of	20,000	18,000	
Rolled beam encased in stone concrete (not more than 1:5½ mix) as follows:  *1½" min. Continuous concrete slab - each side 2" min. protection*		20,000	
Extreme fiber of pins	30,000	27,000	
SHEARING			
Rivets - power driven	15,000	13,500	
Pins and turned bolts in reamed or drilled holes	15,000	13,500	
Unfinished bolts	10,000	10,000	
Webs of beams and plate girders, gross section	13,000	12,000	
BEARING	Double Shear / Single Shear	Double Shear / Single Shear	
Rivets	40,000 / 32,000	30,000 / 24,000	
Turned bolts in reamed or drilled holes	40,000 / 32,000	30,000 / 24,000	
Unfinished bolts	25,000 / 20,000	20,000 / 16,000	
Pins	32,000	30,000 / 24,000	
Expansion rollers and rockers (lbs. per linear inch).	600d	600d	
CAST STEEL			
Tension		16,000	
Compression		16,000	
For A.I.S.C. - Compression and bearing same as for structural steel. Other unit stresses 75% of those for structural steel			
CAST IRON			
Tension		3,000	
Shear		3,000	
Bending - Extreme fiber			
Compression side		16,000	
Tension side		3,000	
Compression on columns with maximum $l/r = 70$		$9{,}000-40l/r$	
WELDED JOINTS			
Compression on section through throat	20,000	15,000	
Tension " " " "	16,000	13,000	
Shear " " " " of fillet weld	13,600	11,300	
Shear " " " " of butt weld	13,000	11,300	

Bending - Fiber stresses shall not exceed values given above for compression and tension, respectively





Notation: In Table "A":
l = length in inches.
b = width of compression flange in inches.
r = radius of gyration in inches.
d = diameter in inches.

STRUCTURAL - UNIT STRESSES

TABLE A - WORKING STRESSES FOR STRUCTURAL LUMBER.

STRESSES FOR JOISTS AND PLANKS, BEAMS AND STRINGERS, POSTS AND TIMBERS

1 Species and commercial grade [1]		2 Rules under which graded	Allowable Unit Stresses in Pounds per Square Inch: 3 Extreme fiber in bending "f" and tension parallel to grain [2] "t"	4 Horizontal shear "H"	5 Compression perpendicular to grain "c⊥"	6 Modulus of elasticity "E"	7 Compression parallel to grain (for solid columns and solid struts) for ratios of length-to-least-dimension (l/d): l/d 11 or less "C" [3]	l/d 14	l/d 17	l/d 20	l/d 23	l/d 26	l/d 30	l/d 35	l/d 40	l/d 50
ASH, WHITE:																
2150 f Grade	J.&P.	National Hardwood Lumber Association	2150	145	600	1,500,000	1700	1586	1452	1224	932	730	548	403	308	197
1900 f Grade	J.&P.—B.&S.		1900	145			1550	1421	1328	1170	932	730				
1700 f Grade	J.&P.—B.&S.		1700	145			1325	1271	1206	1087	928	730				
1450 f Grade	J.&P.—B.&S.		1450	120			1150	1114	1073	1003	892	730				
1300 f Grade	B.&S.		1300	120			1050	1023	991	939	855	731				
1450 c Grade	P.&T.						1450	1379	1295	1154	932	730				
1200 c Grade	P.&T.						1200	1159	1111	1031	904	730				
1075 c Grade	P.&T.						1075	1046	1012	954	862	728				
BEECH:																
2150 f Grade	J.&P.	National Hardwood Lumber Association	2150	145	600	1,600,000	1750	1640	1509	1288	995	779	584	430	329	210
1900 f Grade	J.&P.—B.&S.		1900	145			1525	1453	1368	1225	995					
1700 f Grade	J.&P.—B.&S.		1700	145			1350	1300	1241	1139	983					
1450 f Grade	J.&P.—B.&S.		1450	120			1150	1119	1082	1020	922					
1550 c Grade	P.&T.						1550	1474	1384	1234	995					
1450 c Grade	P.&T.						1450	1388	1314	1188	992					
1200 c Grade	P.&T.						1200	1165	1123	1054	943					
BIRCH:																
2150 f Grade	J.&P.	National Hardwood Lumber Association	2150	145	600	1,600,000	1750	1640	1509	1288	995	779	584	430	329	210
1900 f Grade	J.&P.—B.&S.		1900	145			1525	1453	1368	1225	995					
1700 f Grade	J.&P.—B.&S.		1700	145			1350	1300	1241	1139	983					
1450 f Grade	J.&P.—B.&S.		1450	120			1150	1119	1082	1020	922					
1550 c Grade	P.&T.						1550	1474	1384	1234	995					
1450 c Grade	P.&T.						1450	1388	1314	1188	992					
1200 c Grade	P.&T.						1200	1165	1123	1054	943					
CHESTNUT:																
1450 f Grade	J.&P.	National Hardwood Lumber Association	1450	120	360	1,000,000	1200	1110	1003	823	622	486	365	269	206	132
1200 f Grade	J.&P.—B.&S.		1200	120			950	905	862	763						
1075 c Grade	P.&T.						1075	1009	932	802						
CYPRESS, SOUTHERN:																
1700 f Grade	J.&P.—B.&S.	National Hardwood Lumber Association	1700	145	360	1,200,000	1425	1320	1196	986	746	583	438	322	247	158
1300 f Grade	J.&P.—B.&S.		1300	120			1125	1072	1011	907						
1450 c Grade	P.&T.						1450	1338	1208	986						
1200 c Grade	P.&T.						1200	1136	1062	938						
CYPRESS, TIDEWATER RED:																
1700 f Grade	J.&P.—B.&S.	Southern Cypress Manufacturers Assn.	1700	145	360	1,200,000	1425	1320	1196	986	746	583	438	322	247	158
1300 f Grade	J.&P.—B.&S.		1300	120			1125	1072	1011	907						
1450 c Grade	P.&T.						1450	1338	1208	988						
1200 c Grade	P.&T.						1200	1136	1062	936						
DOUGLAS FIR, COAST REGION: [8]																
Par. 214a Grade [7]	J.&P.	West Coast Bureau of Lumber Grades and Inspection	2150	145	455	1,600,000	1550	1474	1384	1234	995	779	584	430	329	210
Par. 218a Grade [7]	B.&S.		2150	145	455		1550	1474	1384	1234	995	779				
Par. 214 Grade	J.&P.		1900	120	415		1450	1388	1314	1188	992	779				
Par. 218 Grade	B.&S.		1900	120	415		1450	1388	1314	1188	992	779				
Par. 215a Grade [7]	J.&P.		1700	145	455		1325	1277	1222	1126	977	779				
Par. 219a Grade [7]	B.&S.		1700	145	455		1325	1277	1222	1126	977	779				
Par. 215 Grade	J.&P.		1450	120	390		1200	1165	1123	1054	943	779				
Par. 219 Grade	B.&S.		1450	120	390		1200	1165	1123	1054	943	779				
Par. 216 Grade	J.&P.		1100	110	390		1075	1048	1019	969	889	772				
Par. 210a Grade [7]	P.&T.				455		1550	1474	1384	1234	995	779				
Par. 210 Grade	P.&T.				415		1450	1388	1314	1188	992	779				
Par. 200 Grade [4]	P.&T.				390		1325	1277	1222	1126	977	779				
DOUGLAS FIR, INLAND EMPIRE:																
Select Structural [7]	J.&P.—B.&S.	Western Pine Association	2150	145	455	1,600,000	1750	1640	1509	1288	995	779	584	430	329	210
Structural	J.&P.—B.&S.		1900	100	400	1,500,000	1400	1336	1280	1133	934	730	548	403	308	197
Common Structural	J.&P.—B.&S.		1450	95	380	1,500,000	1250	1204	1150	1059	915					
Select Structural [7]	P.&T.				455	1,600,000	1750	1640	1509	1288	995	779	584	430	329	210
Structural	P.&T.				400	1,500,000	1400	1336	1280	1133	934	730	548	403	308	197
Common Structural	P.&T.				380	1,500,000	1250	1204	1150	1059	915					
ELM, ROCK:																
2150 f Grade	J.&P.	National Hardwood Lumber Association	2150	145	600	1,300,000	1750	1582	1384	1089	808	632	475	349	268	170
1900 f Grade	J.&P.—B.&S.		1900	145			1525	1415	1284	1084	808					
1700 f Grade	J.&P.—B.&S.		1700	145			1350	1273	1184	1031	808					
1450 f Grade	J.&P.—B.&S.		1450	120			1150	1103	1047	952	804					
1550 c Grade	P.&T.						1550	1434	1298	1083	808					
1450 c Grade	P.&T.						1450	1354	1243	1053	808					
1200 c Grade	P.&T.						1200	1146	1082	976	808					
ELM, SOFT:																
1700 f Grade	J.&P.	National Hardwood Lumber Association	1700	120	300	1,200,000	1225	1158	1079	946	746	583	438	322	247	158
1450 f Grade	J.&P.—B.&S.		1450	120			1050	1007	958	873	739	583				
1200 f Grade	J.&P.—B.&S.		1200	120			875	851	822	773	687	584				
1075 c Grade	P.&T.						1075	1030	977	887	746	583				
GUM, BLACK AND RED:																
1700 f Grade	J.&P.	National Hardwood Lumber Association	1700	120	300	1,200,000	1225	1158	1079	946	746	583	438	322	247	158
1450 f Grade	J.&P.—B.&S.		1450	120			1050	1007	958	873	739	583				
1200 f Grade	J.&P.—B.&S.		1200	120			875	851	822	773	687	584				
1075 c Grade	P.&T.						1075	1030	977	887	746	583				
HEMLOCK, EASTERN:																
Select Structural	J.&P.—B.&S.	Northern Hemlock and Hardwood Manufacturers Association	1300	85	360	1,100,000	850	824	792	740	656	535	402	295	228	148
Prime Structural	J.&P. [5]		1200	60			775	755	732	691	629	536	402			
Common Structural	J.&P. [5]		1100	60			650	638	624	601	563	508	402			
Utility Structural	J.&P. [5]		950	60			600	590	580	561	532	488	403			
Select Structural	P.&T.						850	824	792	740	656	535	402			
HEMLOCK, WEST COAST: [8]																
Par. 490 Grade	J.&P.	West Coast Bureau of Lumber Grades and Inspection	1450	100	360	1,400,000	1075	1042	1003	937	834	680	511	378	288	184
Par. 500 Grade	B.&S.		1450	100			1075	1042	1003	937	834	680				
Par. 499 Grade	J.&P.		1100	90			850	834	814	781	730	654				
Par. 503 Grade [4]	P.&T.						1075	1042	1003	937	834	680				

The working stresses given in Table "A" above & on page 1.04 are for long-continued or permanent loads.

For footnotes see bottom of Table "A" page 1.04.

Data from Working Stresses For Structural Lumber by National Lumber Manufacturers Association.

STRUCTURAL - UNIT STRESSES

TABLE A- WORKING STRESSES FOR STRUCTURAL LUMBER (CONT.)

STRESSES FOR JOISTS AND PLANKS, BEAMS AND STRINGERS, POSTS AND TIMBERS

1 Species and commercial grade[1]		2 Rules under which graded	Allowable Unit Stresses in Pounds per Square Inch: 3 Extreme fiber in bending "f" and tension parallel to grain[2] "t"	4 Horizontal shear "H"	5 Compression perpendicular to grain "c⊥"	6 Modulus of elasticity "E"	7 Compression parallel to grain (for solid columns and solid struts) for ratios of length-to-least-dimension (l/d): l/d 11 or less "C"[3]	l/d 14	l/d 17	l/d 20	l/d 23	l/d 25	l/d 30	l/d 35	l/d 40	l/d 50
HICKORY:																
2150 f Grade	J.&P.—B.&S.		2150	145			1725	1642	1544	1378	1119					
1900 f Grade	J.&P.—B.&S.		1900	145			1550	1490	1418	1296	1107					
1700 f Grade	J.&P.—B.&S.	National Hardwood Lumber Association	1700	145	720	1,800,000	1350	1311	1264	1185	1061	876	658	483	370	237
1550 c Grade	P.&T.						1550	1490	1418	1296	1107					
1450 c Grade	P.&T.						1450	1401	1343	1246	1092					
1325 c Grade	P.&T.						1325	1288	1243	1169	1051					
LARCH:																
Select Structural[7]	J.&P.—B.&S.		2150	145	455		1750	1582	1384	1069						
Structural	J.&P.—B.&S.		1900	120	415		1450	1354	1243	1053						
Common Structural	J.&P.—B.&S.	Western Pine Association	1450	120	390	1,300,000	1325	1252	1167	1023	808	632	475	349	268	170
Select Structural[7]	P.&T.				455		1750	1582	1384	1069						
Structural	P.&T.				415		1450	1354	1243	1053						
Common Structural	P.&T.				390		1325	1252	1167	1023						
MAPLE, HARD:																
2150 f Grade	J.&P.		2150	145			1750	1640	1509	1288	995					
1900 f Grade	J.&P.—B.&S.		1900	145			1525	1453	1368	1225	995					
1700 f Grade	J.&P. B.&S.	National Hardwood Lumber Association	1700	145			1350	1300	1241	1139	983					
1450 f Grade	J.&P. B.&S.		1450	120	600	1,600,000	1150	1119	1082	1020	922	779	584	430	329	210
1550 c Grade	P.&T.						1550	1474	1384	1234	995					
1450 c Grade	P.&T.						1450	1388	1314	1188	992					
1200 c Grade	P.&T.						1200	1165	1123	1054	943					
OAK, RED AND WHITE:																
2150 f Grade	J.&P.		2150	145			1550	1463	1362	1190	932	730				
1900 f Grade	J.&P.—B.&S.		1900	145			1375	1315	1243	1122	932	730				
1700 f Grade	J.&P.—B.&S.		1700	145			1200	1159	1111	1031	904	730				
1450 f Grade	J.&P.—B.&S.	National Hardwood Lumber Association	1450	120	600	1,500,000	1050	1023	991	939	855	731				
1300 f Grade	B.&S.		1300	120			950	930	906	866	804	712	548	403	308	197
1325 c Grade	P.&T.						1325	1271	1206	1097	928	730				
1200 c Grade	P.&T.						1200	1159	1111	1031	904	730				
1075 c Grade	P.&T.						1075	1046	1012	954	862	728				
PECAN:																
2150 f Grade	J.&P.—B.&S.		2150	145			1725	1642	1544	1378	1119					
1900 f Grade	J.&P.—B.&S.		1900	145			1550	1490	1418	1296	1107					
1700 f Grade	J.&P.—B.&S.	National Hardwood Lumber Association	1700	145	720	1,800,000	1350	1311	1264	1185	1061	876	658	483	370	237
1550 c Grade	P.&T.						1550	1490	1418	1296	1107					
1450 c Grade	P.&T.						1450	1401	1343	1246	1092					
1325 c Grade	P.&T.						1325	1288	1243	1169	1051					
PINE, NORWAY:																
Prime Structural	J.&P.[5]	Northern Hemlock and Hardwood Manufacturers Association	1200	75			900	874	842	790	707	583	438			
Common Structural	J.&P.[5]		1100	75	360	1,200,000	775	758	738	704	650	572	438	322	247	158
Utility Structural	J.&P.[5]		950	75			650	640	628	608	577	531	439			
PINE, SOUTHERN LONGLEAF:																
Select Structural[7]	J.&P.—B.&S.		2400	120[6]			1750	1640	1509	1288	995	779				
Prime Structural[7]	J.&P.—B.&S.		2150	120[6]			1550	1474	1384	1234	995	779				
Merchantable Structural[7]	J.&P.—B.&S.		1900	120[6]			1450	1388	1314	1188	992	779				
Structural S.E.&S.[7]	J.&P.—B.&S.		1900	120[6]			1450	1388	1314	1188	992	779				
No. 1 Structural[7]	J.&P.—B.&S.	Southern Pine Inspection Bureau of the Southern Pine Association	1700	120[6]			1200	1165	1123	1054	943	779				
No. 1 Dimension[7]	J.&P.[5]		1700				1200	1165	1123	1054	943	779				
No. 2 Stress Dimension[7]	J.&P.[5]		1250		455	1,600,000	1025	1003	977	934	865	764	584	430	329	210
Select Structural[7]	P.&T.						1750	1640	1509	1288	995	779				
Prime Structural[7]	P.&T.						1550	1474	1384	1234	995	779				
Merchantable Structural[7]	P.&T.						1450	1388	1314	1188	992	779				
Structural S.E.&S.[7]	P.&T.						1450	1388	1314	1188	992	779				
No. 1 Structural[7]	P.&T.						1200	1165	1123	1054	943	779				
PINE, SOUTHERN SHORTLEAF:																
Dense Select Structural[7]	J.&P.—B.&S.		2400	120[6]	455		1750	1640	1509	1288	995	779				
Dense Structural[7]	J.&P.—B.&S.		2150	120[6]	455		1550	1474	1384	1234	995	779				
Dense Structural S.E.&S.[7]	J.&P.—B.&S.		1900	120[6]	455		1450	1388	1314	1188	992	779				
Dense No. 1 Structural[7]	J.&P.—B.&S.		1700	120[6]	455		1200	1165	1123	1054	943	779				
No. 1 Dense Dimension[7]	J.&P.[5]	Southern Pine Inspection Bureau of the Southern Pine Association	1700		455		1200	1165	1123	1054	943	779				
No. 1 Dimension	J.&P.[5]		1450		390		1075	1049	1019	969	889	772				
No. 2 Dense Stress Dimension[7]	J.&P.[5]		1250		456	1,600,000	1025	1003	977	934	865	764	584	430	329	210
No. 2 Med. Grain Stress Dimension	J.&P.[5]		1100		390		875	861	845	817	774	711				
Dense Select Structural[7]	P.&T.				455		1750	1640	1509	1288	995	779				
Dense Structural[7]	P.&T.				455		1550	1474	1384	1234	995	779				
Dense Structural S.E.&S.[7]	P.&T.				455		1450	1388	1314	1188	992	779				
Dense No. 1 Structural[7]	P.&T.				455		1200	1165	1123	1054	943	779				
POPLAR, YELLOW:																
1500 f Grade	J.&P.	National Hardwood Lumber Association	1500	110			1200	1128	1038	889	684					
1250 f Grade	J.&P.—B.&S.		1250	110	300	1,100,000	960	913	869	794	678	635	402	295	226	145
1075 c Grade	P.&T.						1075	1021	958	851	684					
REDWOOD:																
Dense Sel. All-Heart Structural[7]	J.&P.—B.&S.		1700	110			1450	1338	1208	986						
Select All-Heart Structural[7]	J.&P.—B.&S.		1450	95			1325	1239	1140	969						
Bulkhead Structural[7]	J.&P.	California Redwood Association	1300	95	320	1,200,000	1325	1239	1140	969	746	583	438	322	247	158
Heart Structural	J.&P.		1300	95			1325	1239	1140	969						
Dense Sel. All-Heart Structural[7]	P.&T.						1450	1338	1208	986						
Select All-Heart Structural[7]	P.&T.						1325	1239	1140	969						
SPRUCE, EASTERN:																
1450 f Structural Grade	J.&P.	Northeastern Lumber Manufacturers Association, Inc.	1450	110			1050	1007	958	873	739					
1300 f Structural Grade	J.&P.		1300	95	300	1,200,000	975	941	901	833	726	583	438	322	247	158
1200 f Structural Grade	J.&P.		1200	95			900	874	842	790	707					
TUPELO:																
1700 f Grade	J.&P.		1700	120			1225	1158	1079	946	746	583				
1450 f Grade	J.&P.—B.&S.	National Hardwood Lumber Association	1450	120	360	1,200,000	1050	1007	958	873	739	583	438	322	247	158
1200 f Grade	J.&P. B.&S.		1200	120			875	851	822	773	697	584				
1075 c Grade	P.&T.						1075	1030	977	887	746	583				

[1] Abbreviations: J.&P., Joists and Planks; B.&S., Beams and Stringers; P.&T., Posts and Timbers; S.E.&S., Square Edge and Sound.
[2] When graded in accordance with par. 310 of Misc. Pub. 185 U. S. Dept. of Agr.
[3] When graded according to par. 310 of Misc. Pub. 185 U. S. Dept. of Agr. and when the l/d ratio is 11 or less.
[4] When slope of grain is not more than 1 in 10.
[5] Available in thickness of 2 inches only.
[6] Allowable unit shearing stresses 20, 40, and 60 percent higher than these tabulated values shall be used when these grades are specified to conform to standard 120, 140, and 160 pound shear grading rules instead of the otherwise standard 100 pound shear grading rule.
[7] These grades include requirements for density.
[8] These paragraph numbers refer to paragraphs in the Standard Grading and Dressing Rules of the West Coast Bureau of Lumber Grades and Inspection.

Data from Working Stresses for Structural Lumber by National Lumber Manufacturers Association.

STRUCTURAL - UNIT STRESSES & STRENGTH OF MATERIALS

TABLE A — WORKING STRESSES - MASONRY (In p.s.i.)

KIND OF MASONRY		COMPRESSION - GROSS AREA OF CROSS SECTION: NEW YORK CITY CODE: CEM. LIME[2] MORTAR	NEW YORK CITY CODE: CEMENT[3] MORTAR	DEPT. OF COMMERCE 1924: CEM. LIME[2] MORTAR	DEPT. OF COMMERCE 1924: CEMENT[3] MORTAR
Granite		640	800	640	800
Gneiss		600	750	–	–
Limestone		400	500	400	500
Marble		400	500	400	500
Sandstone		250	300	320	400
Bluestone		300	400	–	–
Natural Stone	Cut	110	140	–	–
	Uncut	110	140	–	–

KIND OF MASONRY	COMPRESSION - GROSS AREA OF CROSS SECTION: NEW YORK CITY CODE: CEM. LIME[2] MORTAR	NEW YORK CITY CODE: CEMENT[3] MORTAR	DEPT. OF COMMERCE 1924: CEM. LIME[2] MORTAR	DEPT. OF COMMERCE 1924: CEMENT[3] MORTAR
Brick - Solid	250	325	130[1]	170[1]
Brick - Hollow Wall	125	150	70	80
Struct Clay Tile - Cells Vert.	100	125	70	80
Struct Clay Tile - Cells Hor.	60	70	70	80
Conc. Block or Tile	60	70	70	80
Solid Conc. Units	125	150	–	–
Plain Conc.[4] 1:7 Mix	400			
Plain Conc. 1:8 Mix			400	

[1] May be increased 50% for local concentrated loads or eccentric loading.
[2] Cement lime mortar: A mortar composed of 1 part Portland cement, 1 part hydrated lime to not more than 6 parts of sand - proportioned by volume.
[3] Cement mortar: A mortar composed of 1 part Portland cement to not more than 3 parts of sand, proportioned by volume, with an allowable addition of hydrated lime or lime putty not to exceed 15% of the cement by volume.
[4] For greater strength concrete use 25% of the ultimate stress.

TABLE B — PROPERTIES OF STRUCTURAL MATERIALS

SUBSTANCE	SPECIFIC GRAVITY	ULTIMATE STRESS. In Lb. per Sq. In.	ELASTIC LIMIT. In Lb. per Sq. In.	MODULUS OF ELASTICITY. In Lb. per Sq. In.	COEFFICIENT OF LINEAR EXPANSION. For 1° F.
Aluminum, Structural 17 ST	2.79	60,000 Ten.	37,000 Ten. Comp	10,300,000	.0000114
Iron, Cast, Gray	7.2	25,000 - 33000 Bend 18,000 - 74,000 Ten.		12,000,000	.0000059
Iron, Wrought	7.75	48,000 Ten.	26,000 Ten.	28,000,000	.0000067
Steel, Structural	7.85	60,000 - 72,000	33,000 Ten.	29,000,000	.0000067
Steel, Intermediate Grade Reinf. Bars	7.85	70,000 - 90,000	40,000	29,000,000	.0000067
Steel, Hard Grade Reinf. Bars	7.85	80,000	50,000	29,000,000	.0000070
Steel, Structural nickel (3.25% Ni).		85,000 - 100,000	50,000	29,000,000	
Glass (common)	2.4 - 2.6	2,000 - 3000 - Ten. 6,000 - 12,000 - Comp.		10,000,000	.0000047
Clay Brick (common)	1.92	4,000 COMP. 200 TENSION 600 BENDING.		2,000,000	.0000031
Concrete - 3,000# f'c	2.3			3,000,000	.0000079
Stone - Granite	2.7	12,000 COMP. 1,200 TENSION 1,600 BENDING		7,000,000	.0000047
" Limestone	2.5	8,000 COMP. 800 TENSION 1,500 BENDING		7,000,000	.0000044
" Marble	2.7	8,000 COMP. 800 TENSION 1,500 BENDING		7,000,000	.0000056
" Sandstone	2.3	5,000 COMP. 150 TENSION 1,200 BENDING.		3,000,000	.0000061
Wood - Douglas Fir (Rocky Mt. Region)	.48	6,400 - 9600 Bending.		1,200,000	.0000021 - With grain .000032 - Across "
" - Pine Southern S.L. Yellow	.58	7,300 - 12,800 Bending.		1,600,000	.000003 - With grain. .000019 - Across "

TABLE C — WIRE ROPE 6 x 19 STANDARD HOISTING — PLOW STEEL.

Diameter, Inch	2 3/4	2 1/4	2	1 7/8	1 3/4	1 5/8	1 1/2	1 3/8	1 1/4	1 1/8	1	7/8	3/4	5/8	9/16	1/2	7/16	3/8
Breaking Strength Tons of 2000 Lbs.	254.0	174.0	139.0	123.0	108.0	93.4	80.0	67.5	56.2	45.7	36.4	28.0	20.7	14.5	11.8	9.35	7.19	5.31

Table C - from John A. Roebling's Sons. Co.

STRUCTURAL - EARTHQUAKES

LATERAL BRACING OF STRUCTURES BASED ON PACIFIC COAST UNIFORM BUILDING CODE - 1943.

SUPERSTRUCTURE:

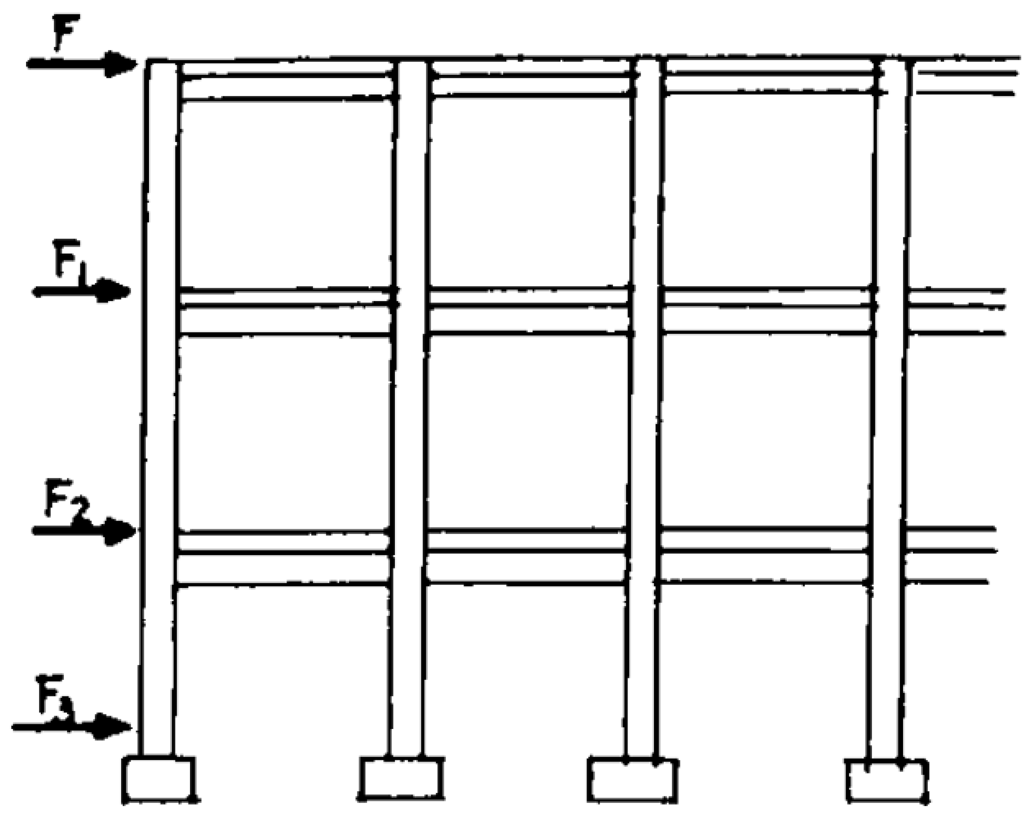
Design structure as a whole and every portion of same to resist lateral forces applied at each floor or roof level above foundations.

Horizontal Force, "F" = CW in lbs.

where:

C = Force factor; factor from Table A adjusted for zone.

W = Total D.L + ½ L.L. at and above point under consideration except for warehouses and tanks where W = Total D.L + Total L.L.

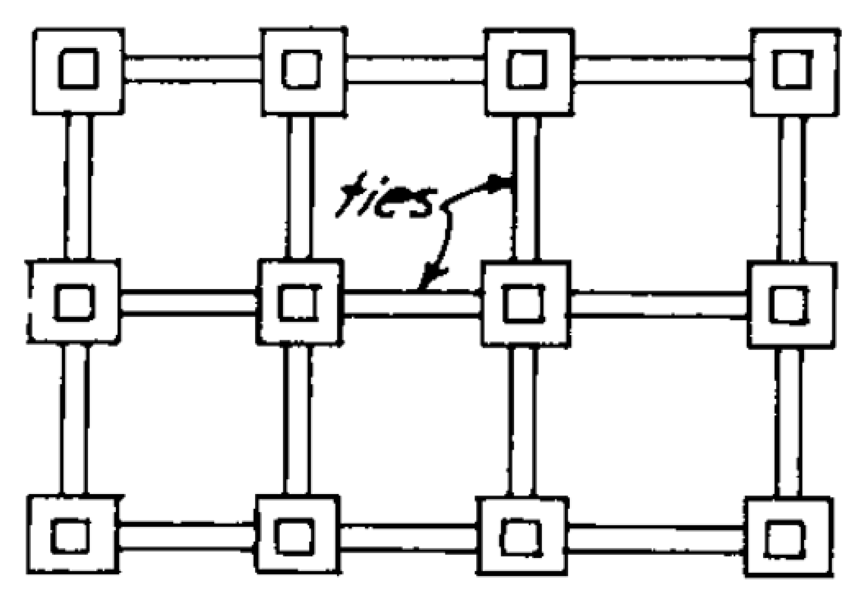


TYPICAL BENT.

FOUNDATIONS:

All foundations on piles or soil with less than 2000 #/ft² bearing value shall have footings interconnected with ties in two directions at 90° to each other.

Strength of tie shall equal 10% of vertical load of heavier footing connected.



FOUNDATION PLAN.

GENERAL DESIGN DATA:

Stresses shall not be more than 33⅓% above allowable working stresses in code except that shear in concrete walls 6" or thicker shall not exceed .05 f'c.

Overturning moment shall not exceed ⅔ of moment of stability both calculated using the same loads.

Calculation of shears and moments shall be in accordance with the wind design.

TABLE A - HORIZONTAL FORCE FACTORS.

Part or Portion	*Value of "C"**	*Direction of Force*
The structure as a whole and every portion not itemized in this table**	.02 on soil, over 2000 lbs. .04 on soil up to 2000 lbs.	Any direction horizontally
Bearing walls, non-bearing walls, partitions, curtain walls, enclosure walls, panel walls	.05 With a minimum of five pounds per square foot.	Normal to surface of wall
Cantilever parapet and other cantilever walls, except retaining walls	.25	Normal to surface of wall
Exterior and interior ornamentations and appendages	.25	Any direction horizontally
Towers, tanks, towers and tanks plus contents, chimneys, smokestacks, and penthouses when connected to or a part of a building	.05	Any direction horizontally

* *See Map Fig. B for zones. The values given "C" are minimum and should be adopted in locations not subject to frequent seismic disturbances, as shown in Zone 1. For locations in Zone 2, "C" should be doubled. For locations in Zone 3, "C" should be multiplied by four.*

** *Where wind load would produce higher stresses, this load should be used in lieu of factor shown.*

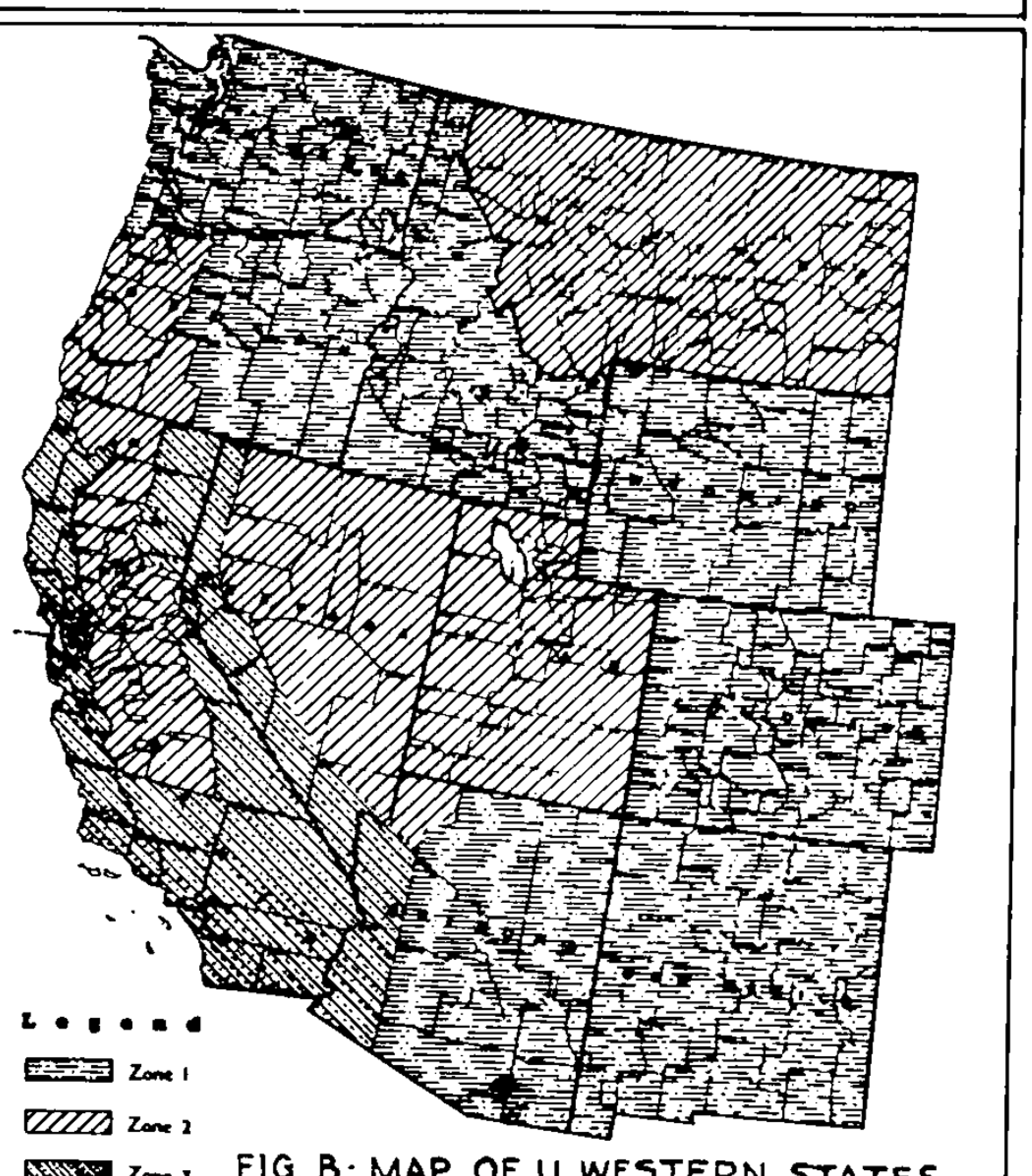


FIG. B - MAP OF 11 WESTERN STATES SHOWING ZONES OF APPROX. EQUAL SEISMIC PROBABILITY.

WALLS: Masonry bearing walls in this area are limited to three stories with a maximum height of 38'-0" above grade. They shall be designed for all vertical and horizontal loads, including dead, live, wind and earthquake loads in accordance with code. Reinforced masonry walls are used in areas subject to greatest disturbance.

STRUCTURAL - UNIT WEIGHTS

MASONRY WALLS & PARTITIONS

DEAD LOAD WITHOUT PLASTER TYPE OR SUBSTANCE	LBS. PER SQ. FT.	LBS. PER CU. FT.
EXTERIOR WALLS		
Solid brickwork		120
Concrete, stone		144
Granite, blue stone, marble		168
Limestone		156
Sandstone		144
4" brick + 6" hollow block backup		75
4" " " 8" " " "		80
Hollow stone concrete block		62
Hollow cinder " "		48
Solid " " "		87
INTERIOR WALLS & PARTITIONS		
2" T.C. or cem. block (non-bearing)	14	
3" " " " " " "	18	
4" " " " " " "	20	
6" " " " " " "	27	
8" " " " " " "	34	
10" " " " " " "	40	
4" load bearing T.C. or cem. block	22	
6" " " " " " "	31	
8" " " " " " "	36	
10" " " " " " "	42	
12" " " " " " "	52	
2" solid gypsum	9½	
3" " "	13	
3" hollow "	10	
4" " "	12	
6" " "	17	
3⅞" Glass Block	20	

ROOFING & PLASTER OR CEILING FINISHES

TYPE OR SUBSTANCE	LBS. PER SQ. FT.
Wood shingles	2
Asphalt "	3-4
Flat clay tile and cement shingles	16
Clay tile shingles	9
Asbestos shingles or siding	3
2" book tile	12
3" " "	20
Sheet metal roofing	2
Corrugated roofing (No. 20)	2
Corrugated asbestos	3-4
Wood rafters or sheathing	3
Slag roofing	5
5 ply-felt tar and gravel roofing	6
4 " " " " " "	5
3 " " " " " "	4
3 " composition roofing	1
Slate roofing laid in place with 3" double lap — 3/16" and 1/4" thickness	7-9½
Slate roofing laid in place with 3" double lap — 3/8" thickness	14½
Slate roofing laid in place with 3" double lap — 1/2" "	19½
Skylight- frame and glass	10
Plate glass per inch thickness	14
Hung ceiling-met. lath & Port. cem. plaster	10
" " lime or gypsum plaster	8
Lime or gypsum plaster on walls (direct)	5
" " " " " slabs "	6
2 x 4 studs plastered each side	14
Channel studs, met. lath & cem. plaster-2" thick	20

FLOORING & FLOOR SLABS

TYPE OR SUBSTANCE	LBS. PER SQ. FT.
Cinder fill per inch of thickness	5
Cement finish per inch of thickness	12
Terrazzo, 1½" thick	18
Tile and setting bed	15-23
Marble and " "	25-30
Asphalt mastic flooring - 1½" thick	18
Linoleum or asphalt finish	2
Hardwood flooring - 7/8" thick	4
Soft wood sub " 7/8" "	3
2x4 sleepers and fill	10
Oak & longleaf yel. pine in lbs. per cu. ft.	48
Spruce, fir, hemlock, white pine - lbs. per c.f.	30
3" creosoted wood flooring	15
PATENTED STRUCTURAL SYSTEMS	
Gypsteel plank - 2" thick	12
Sheetrock-Pyrofill - 2½" thick	12
Featherweight nailing conc. - 2½" thick	19
" channel slabs - 2¾" "	10
Porete roof slabs (with ½" nailing fin.) 2½" "	15
Porete channel slabs - 3½" thick	12
Cinder plank - 2" thick	15
Aerocrete lightweight conc. - lbs per c.f.	50-80
Nalecode - lbs. per c.f.	75
METAL TILE & JOIST 20" WIDE PANS & 5" JOISTS	
4" deep plus 2½" topping	45
6" " " " "	50
8" " " " "	56
10" " " " "	64
12" " " " "	69
14" " " " "	75
ONE WAY CLAY TILE - 16" WIDE TILE & 4" JOISTS	
4" deep with no topping	27
5" " " " "	31
6" " " " "	37
7" " " " "	42
8" " " " "	46
9" " " " "	50
10" " " " "	54
12" " " " "	62
TWO WAY SLAG BLOCK - 16"x16" BLOCKS & 4" JOISTS	
4½ deep with no topping	39
6" " " " "	49
7" " " " "	54
8" " " " "	59
9" " " " "	67
10" " " " "	74
10" " " 1" "	86
TWO WAY CLAY TILE & JOIST - 16"x16" BLOCKS & 4" JOISTS	
4" deep with no topping	31
4½" " " " "	35
5" " " " "	39
6" " " " "	45
7" " " " "	52
8" " " " "	60
9" " " " "	68
10" " " " "	77

STRUCTURAL - LIVE LOADS

TABLE A - LIVE LOADS IN POUNDS PER SQUARE FOOT.*

Occupancy	Codes						
	Dept. of Commerce 1924	Nat. Bd. of Fire Underwriters 1934	Pacific Coast Bldg. Officials Conference 1937	New York 1938	Chicago[20] 1937	Philadelphia 1929	Detroit 1936
Dwellings, apartment and tenement houses, hotels, club houses, hospitals and places of detention:							
Dwellings, private rooms and apartments	40[1]	40	40	40[11]	40	40	40
Public corridors, lobbies and dining rooms	100	100	100	100	100	100	80
School buildings:							
Class rooms and rooms for similar use	50	50	40[7]	60[12]	50	50[25]	50[25]
Corridors and public parts of the building	100	100	100	100	100	100	80
Theaters, assembly halls and other places of assemblage:							
Auditoriums with fixed seats	50	100	50	75[13]	75	60[26]	80
Lobbies, passageways, gymnasiums, grandstands, stages and auditoriums or places of assemblage without fixed seats	100	100	100[8]	100	100	100	100[33]
Office buildings:							
Office space	50[2,3]	50[2]	50[2,3]	50[11]	50[21]	60	50[34]
Corridors and other public places	100	100	100	100[14]	100	100	125[14]
Workshops, factories and mercantile establishments:							
Manufacturing—light	75	125[2]	75	120	100	120[28,27]	100[35]
" —heavy			125		100	200[28]	
Storage—light	100	125[2]	125	120	100	150[28,29]	125[36]
" —heavy	250		250		100	200[28]	
Stores—retail	75	125[2]	75	75[15]	100	110[28]	100[35]
" —wholesale	100	125[2]	100	120	100	110[28]	100[35]
Garages:							
All types of vehicles	100	125[2]	100[9]	175[16]	100[22]	100[30]	150[37]
Passenger cars only	80	125[2]	100	75[17]	50[23]	100	80[38]
All stairs and fire escapes, except in private residences	100	100	100	100	100	100	100[39]
Roofs (flat)	30	30	20	40	25	30	30
Sidewalks	250[4]	300	250[4]	300[18]		120[31]	250
Wind	10 20[5]	15-30[6]	15-20[10]	0-20[19]	25-35[24]	20[32]	20[40]

The classification used in Table A is based primarily upon that given in the Report of the Building Code Committee of the U.S. Department of Commerce entitled "Minimum Live Loads Allowable for Use in Design of Buildings."

WIND STRESS REDUCTIONS

CONCRETE STRUCTURES:- Increase allowable stresses 1/3 where wind loads are added to live and dead loads.**

STEEL STRUCTURES:- Members subject only to wind, increase allowable stresses 1/3. Members subject to wind and other forces, increase stresses 1/3 but section to be not less than that required for dead, live and impact loads. †

WOOD STRUCTURES:- Increase allowable stresses 1/2 but section to be not less than that required for dead and live load. ††

IMPACT

For structures carrying live loads which induce impact or vibration, the live load stresses shall be increased sufficiently to provide for same. If not otherwise specified, the increase shall be:-

For elevator supports	100 per cent.
For traveling crane supports (girders & columns)	25 " "
For light machinery, shaft or motor driven, not less than	20 " "
For reciprocating machinery or power units, not less than	50 " "

CRANE RUNWAY FORCES

The lateral forces on crane runways to provide for the effect of crane trolleys shall, if not otherwise specified, be 20 per cent of the moving load of the crane applied at the top of rail, one-half on each side of runway and considered as acting in either direction normal to the runway rail.

See Page 1-09 for explanation of foot notes and for live load reductions.

* Data from Reinf. Conc. Design Handbook of the Am. Conc. Institute. ** From A.C.I.

† From A.I.S.C. †† From Wood Handbook of Forest Products Lab.-U.S. Dept. of Agr.

STRUCTURAL - LIVE LOADS

FOOTNOTES FOR TABLE A- ON PAGE 1-08 *

1. 30 for one and two family dwellings with floors of monolithic type or of solid or ribbed slabs.
2. Or 2000 on any space 2½ feet square.
3. Additional load equivalent to a single partition placed in any position.
4. Or 800 concentrated.
5. 10 for portions below 40 ft. and 20 for portions above 40 ft.
6. 15 for portions below 40 ft. and 30 for portions above 40 ft.
7. 60 for library reading rooms and 125 for stackrooms.
8. 150 for armories.
9. Or concentrated rear wheel of loaded truck in any position.
10. 15 for portions below 60 ft. and 20 for portions above 60 ft.
11. Including corridors.
12. For rooms with fixed seats or, by special permission, other small rooms. 120 for library stackrooms.
13. 60 for churches.
14. Including entire first floor.
15. 100 for entire first floor.
16. Or 6000 concentrated. Trucking space and driveways, 24,000 concentrated (For beams, columns and girders 120*% L.L.).
17. Or 2000 concentrated.
18. Or 12,000 concentrated for driveways over sidewalks.
19. 20 for structures over 100 ft. high. Special consideration for others.
20. When dead load exceeds live load, specified live loads may be reduced by ratio of live to dead but not to less than two-thirds.
21. Or 2000 concentrated on any space 3 feet square.
22. Or 3000 concentrated on any space 4 feet square.
23. 100 on first and second floors and alternate of 3000 on area 4 feet square.
24. 25 for surfaces less than 275 ft. high with variable above.
25. Only school class rooms with fixed seats.
26. Churches only.
27. 150 for certain occupancies.
28. Every floor beam 4000 concentrated.
29. 110 for storage of household goods.
30. Or 8000 concentrated.
31. Interior courts, sidewalks, etc., not accessible to a driveway.
32. 25 for isolated structures exposed for full height.
33. 125 for dance halls and drill halls.
34. Above first floor including corridors.
35. 125 for first floor.
36. 150 for first floor.
37. Or 2500 concentrated on area 6 inches square with such concentrations spaced alternately 2 ft. 4 in. and 4 ft. 8 in. in one direction and 5 ft. and 10 ft. in the other direction.
38. Only structures with clear head room of 8 ft. 6 in. or less. Or 1500 concentrated spaced as in 37.
39. 50 for dwellings and apartments under 3 stories.
40. For buildings less than 500 ft. high.

LIVE LOAD REDUCTIONS.

NEW YORK CITY CODE.

(a) Structures for storage purposes - all columns, piers, walls & foundations may be designed for 85% of live load.

(b) In structures intended for other purposes live load reductions for columns, piers, walls and foundations are as follows: 100% L.L. on roof, 85% top floor, 80% next floor and 5% reduction for each successive lower floor provided that in all cases at least 50% of live load is assumed.

(C) Girder members (except in roofs & as specified below) carrying floor loads the equivalent of 200 Sq. Ft. or more may be designed for 85% of live load.

(d) Trusses & girders supporting columns and for determining area of footings, the full dead load & live load may be taken with the reductions as permitted in Par. (b).

DEPT. OF COMMERCE CODE.

Except in buildings for storage purposes, the following reductions in assumed total live loads are permissible, in designing all columns, piers, walls, foundations, trusses and girders.

Reduction of total L.L. carried.

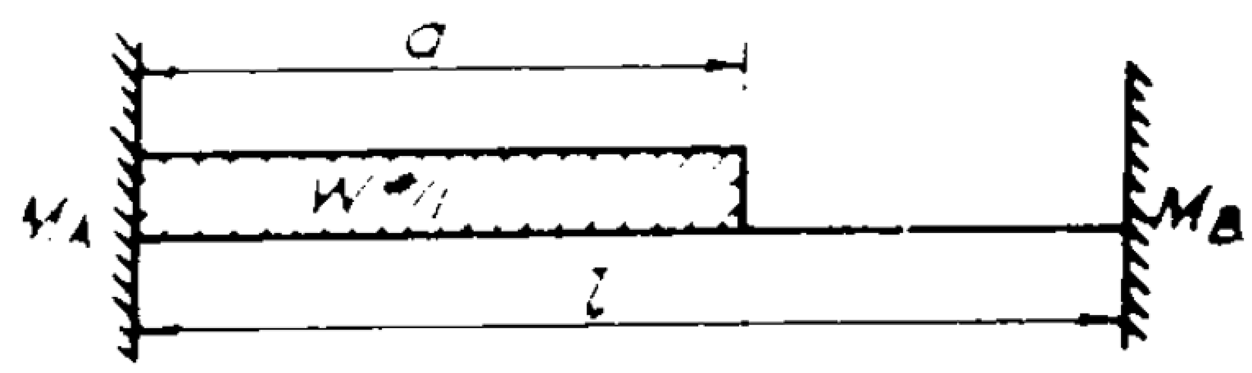
Carrying	1	floor	0%
"	2	"	10 "
"	3	"	20 "
"	4	"	30 "
"	5	"	40 "
"	6	"	45 "
"	7	" or more	50 "

In determining the area of footings the full dead loads plus live loads, with reductions figured as permitted above, shall be taken; except that in bldgs. for human occupancy a further reduction of ½ L.L. as permitted above may be used.

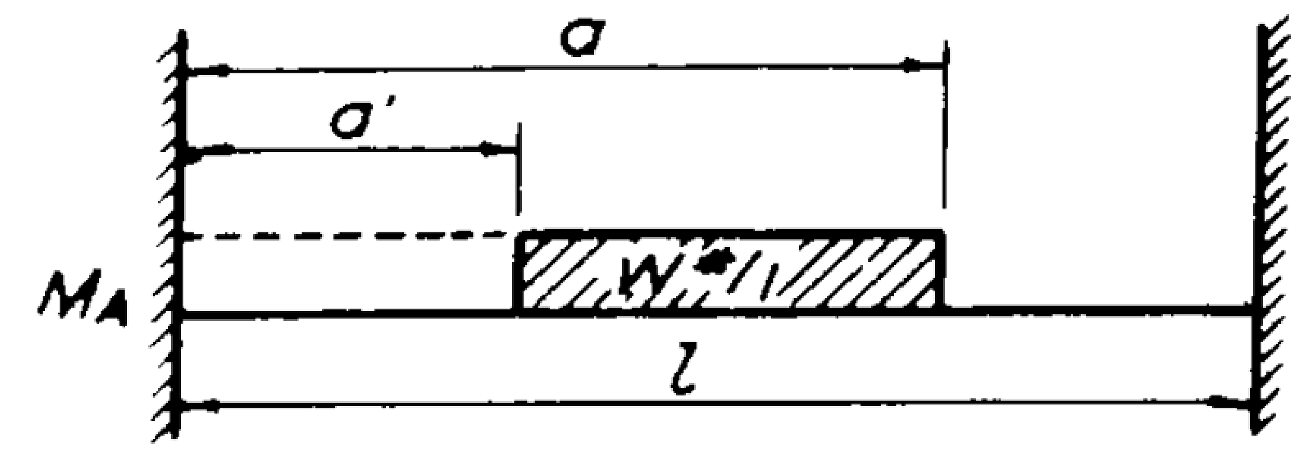
*Data from Reinforced Concrete Design Handbook of the American Concrete Institute.

STRUCTURAL - FIXED END MOMENTS*

TABLE A - FIXED END MOMENTS PARTIAL UNIFORM LOAD.



$M_A = C_A W l^2$
$M_B = C_B W l^2$



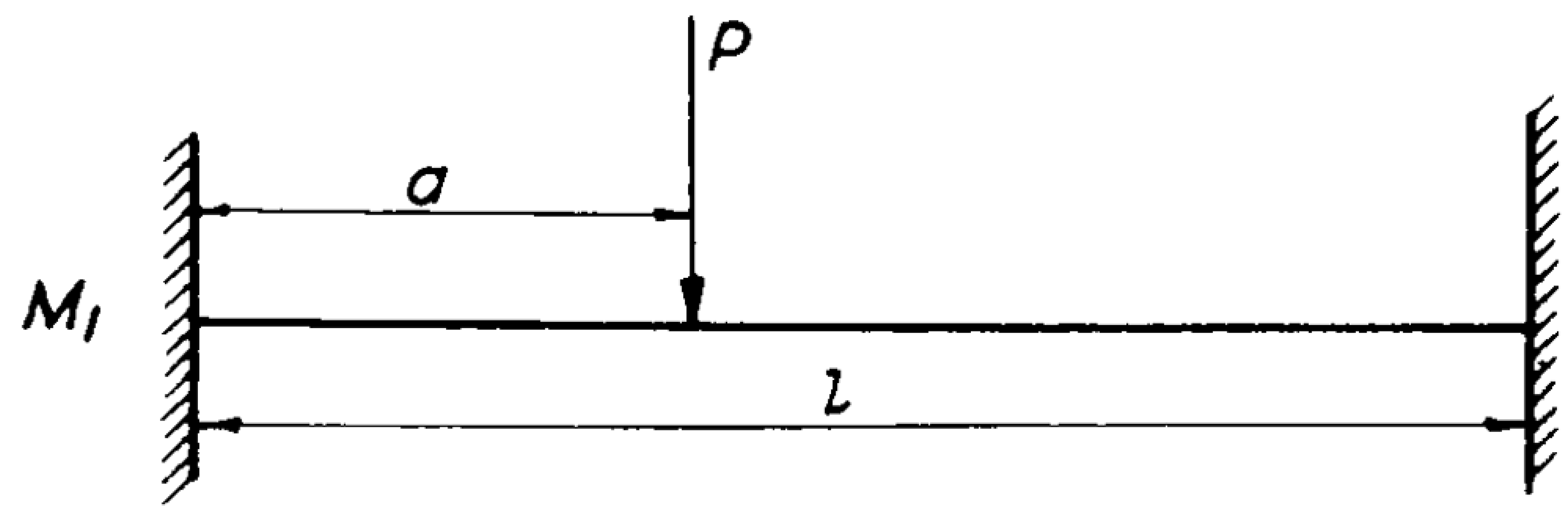
$M_A = C_A W l^2$ (for 'a' distance) $- C_A W l^2$ (for 'a'' distance).

a/l or a'/l	C_A	C_B
.01	.00005	.00000
.02	.00019	.00000
.03	.00043	.00001
.04	.00076	.00002
.05	.00117	.00004
.06	.00166	.00007
.07	.00223	.00011
.08	.00287	.00016
.09	.00358	.00023
.10	.00436	.00031
.11	.00520	.00041
.12	.00610	.00052
.13	.00706	.00066
.14	.00807	.00082
.15	.00913	.00100
.16	.01023	.00120
.17	.01138	.00143
.18	.01257	.00168
.19	.01380	.00196
.20	.01507	.00227
.21	.01636	.00260
.22	.01769	.00296
.23	.01904	.00336
.24	.02041	.00378
.25	.02181	.00423
.26	.02323	.00472
.27	.02466	.00523
.28	.02610	.00578
.29	.02756	.00636
.30	.02902	.00698
.31	.03050	.00762
.32	.03198	.00830
.33	.03346	.00901
.34	.03494	.00976
.35	.03642	.01054
.36	.03790	.01135
.37	.03937	.01220
.38	.04083	.01308
.39	.04229	.01399
.40	.04373	.01493
.41	.04517	.01591
.42	.04659	.01692
.43	.04799	.01796
.44	.04938	.01902
.45	.05075	.02012
.46	.05210	.02125
.47	.05343	.02241
.48	.05474	.02359
.49	.05603	.02480
.50	.05729	.02604
.51	.05853	.02730
.52	.05974	.02859
.53	.06092	.02990
.54	.06208	.03123
.55	.06321	.03258
.56	.06431	.03395
.57	.06538	.03534
.58	.06642	.03675
.59	.06742	.03817
.60	.06840	.03960
.61	.06934	.04105
.62	.07026	.04250
.63	.07113	.04397
.64	.07198	.04544
.65	.07279	.04692
.66	.07357	.04840
.67	.07432	.04988
.68	.07503	.05136
.69	.07571	.05284
.70	.07636	.05431
.71	.07697	.05577
.72	.07755	.05723
.73	.07810	.05868
.74	.07862	.06011
.75	.07910	.06152
.76	.07955	.06292
.77	.07998	.06429
.78	.08037	.06565
.79	.08073	.06697
.80	.08107	.06827
.81	.08137	.06953
.82	.08165	.07076
.83	.08190	.07195
.84	.08213	.07310
.85	.08234	.07421
.86	.08251	.07527
.87	.08267	.07628
.88	.08281	.07723
.89	.08293	.07813
.90	.08302	.07898
.91	.08311	.07975
.92	.08317	.08046
.93	.08322	.08111
.94	.08326	.08167
.95	.08329	.08216
.96	.08331	.08258
.97	.08332	.08290
.98	.08333	.08314
.99	.08333	.08328
1.00	.08333	.08333

* Data from Eng. News Record, June 18, 1942, Article by M.W. Rostenstein.

STRUCTURAL - FIXED END MOMENTS *

TABLE A - FIXED END MOMENTS CONCENTRATED LOADING.



a/l	M_1
.01	.0098 Pl
.02	.0192 "
.03	.0282 "
.04	.0369 "
.05	.0451 "
.06	.0530 "
.07	.0605 "
.08	.0677 "
.09	.0745 "
.10	.0810 "
.11	.0871 "
.12	.0929 "
.13	.0984 "
.14	.1035 "
.15	.1084 "
.16	.1129 "
.17	.1171 "
.18	.1210 "
.19	.1247 "
.20	.1280 "
.21	.1311 "
.22	.1338 "
.23	.1364 "
.24	.1386 "
.25	.1406 "
.26	.1424 "
.27	.1439 "
.28	.1452 "
.29	.1462 "
.30	.1470 "
.31	.1476 "
.32	.1480 "
.33	.1481 "
.34	.1481 "

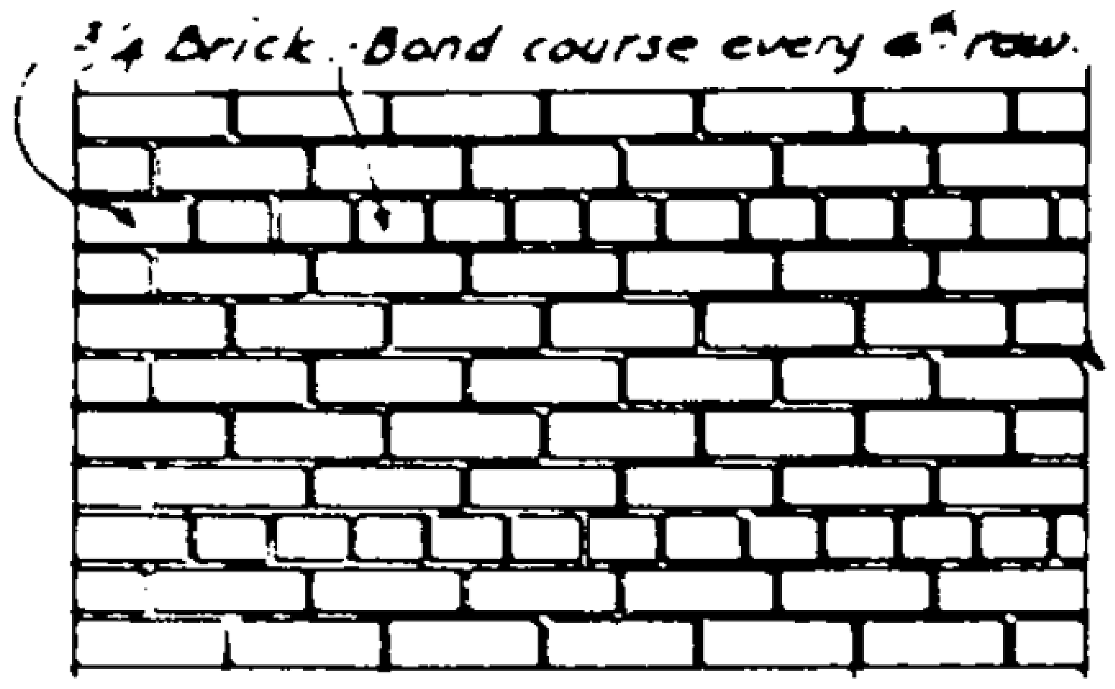
a/l	M_1
.35	.1479 Pl
.36	.1475 "
.37	.1469 "
.38	.1461 "
.39	.1451 "
.40	.1440 "
.41	.1427 "
.42	.1413 "
.43	.1397 "
.44	.1380 "
.45	.1361 "
.46	.1341 "
.47	.1320 "
.48	.1298 "
.49	.1274 "
.50	.1250 "
.51	.1225 "
.52	.1198 "
.53	.1171 "
.54	.1143 "
.55	.1114 "
.56	.1084 "
.57	.1054 "
.58	.1023 "
.59	.0992 "
.60	.0960 "
.61	.0928 "
.62	.0895 "
.63	.0862 "
.64	.0829 "
.65	.0796 "
.66	.0763 "
.67	.0730 "
.68	.0696 "

a/l	M_1
.69	.0663 Pl
.70	.0630 "
.71	.0597 "
.72	.0564 "
.73	.0532 "
.74	.0500 "
.75	.0469 "
.76	.0438 "
.77	.0407 "
.78	.0378 "
.79	.0348 "
.80	.0320 "
.81	.0292 "
.82	.0266 "
.83	.0240 "
.84	.0215 "
.85	.0191 "
.86	.0169 "
.87	.0147 "
.88	.0127 "
.89	.0108 "
.90	.0090 "
.91	.0074 "
.92	.0059 "
.93	.0046 "
.94	.0034 "
.95	.0024 "
.96	.0015 "
.97	.0009 "
.98	.0004 "
.99	.0001 "
1.00	.0000 "

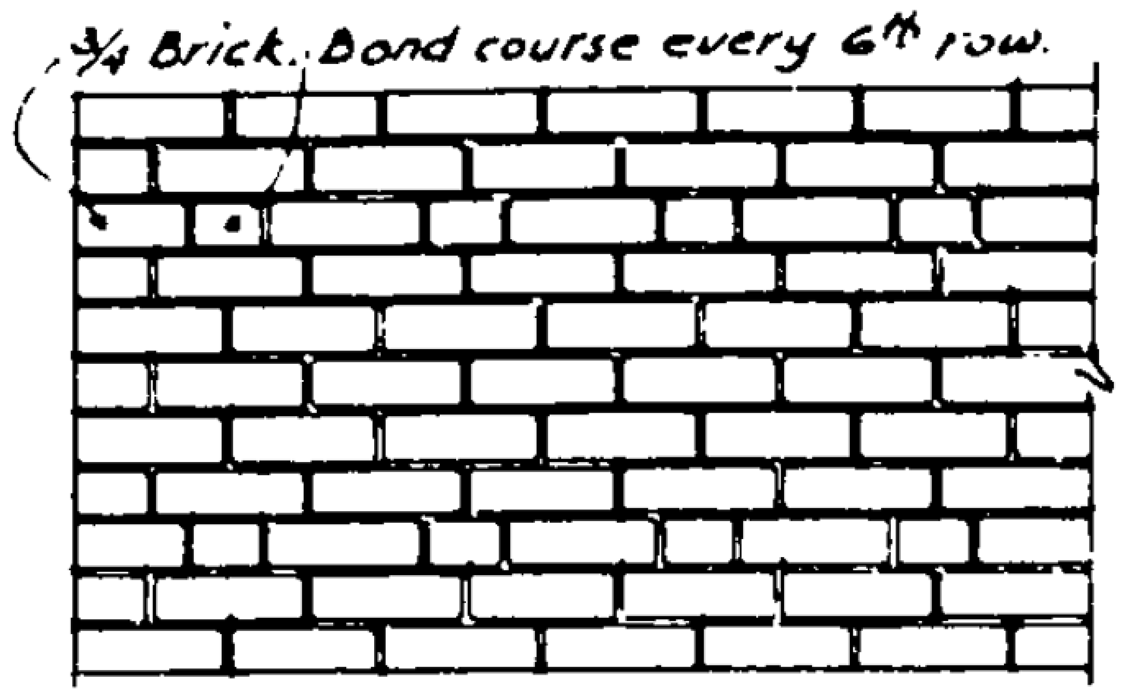
* Data from Eng. News Record, June 18, 1942, Article by M. W. Rostenstein.

STRUCTURAL - BRICK MASONRY

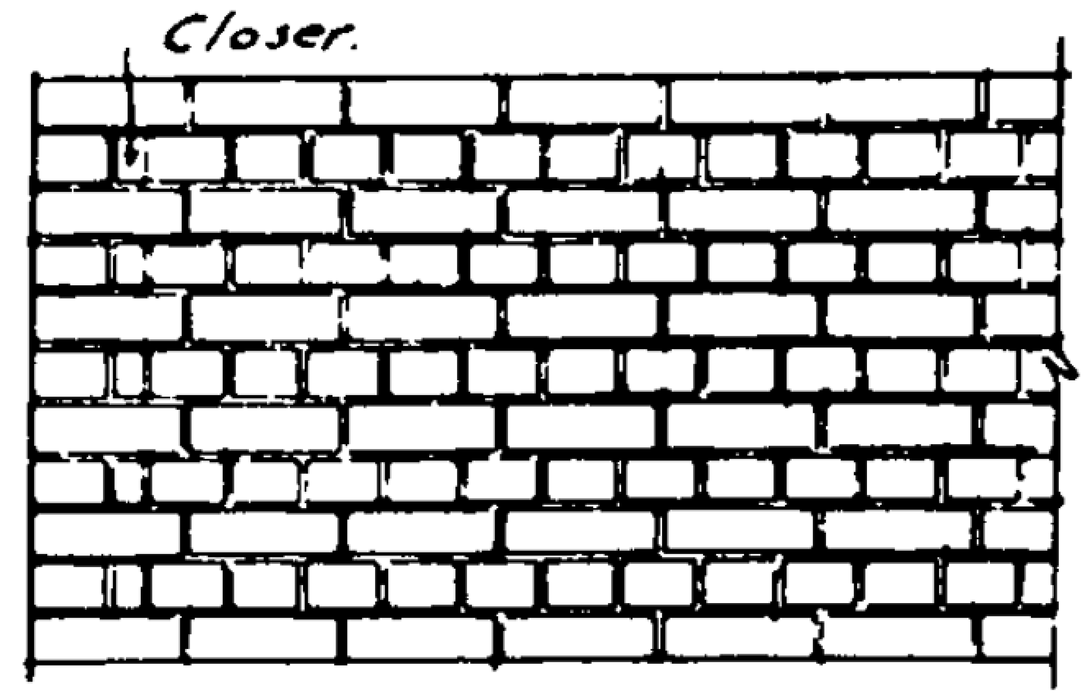
· BRICKWORK ·



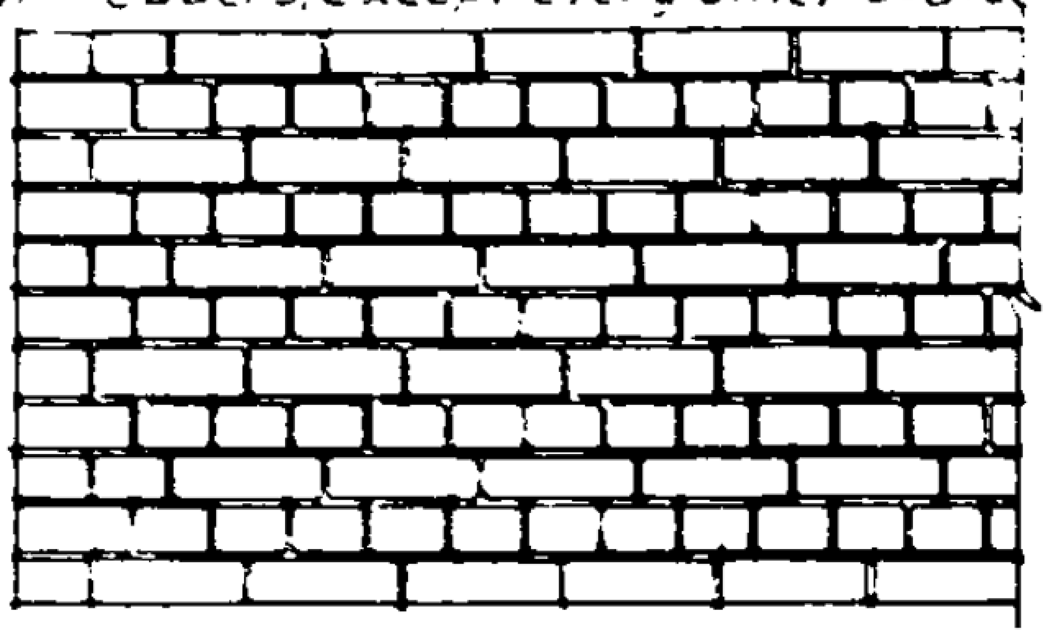
COMMON (Header Bond)
Stretcher or Running Bond, similiar but with-out headers, except every other course at corner



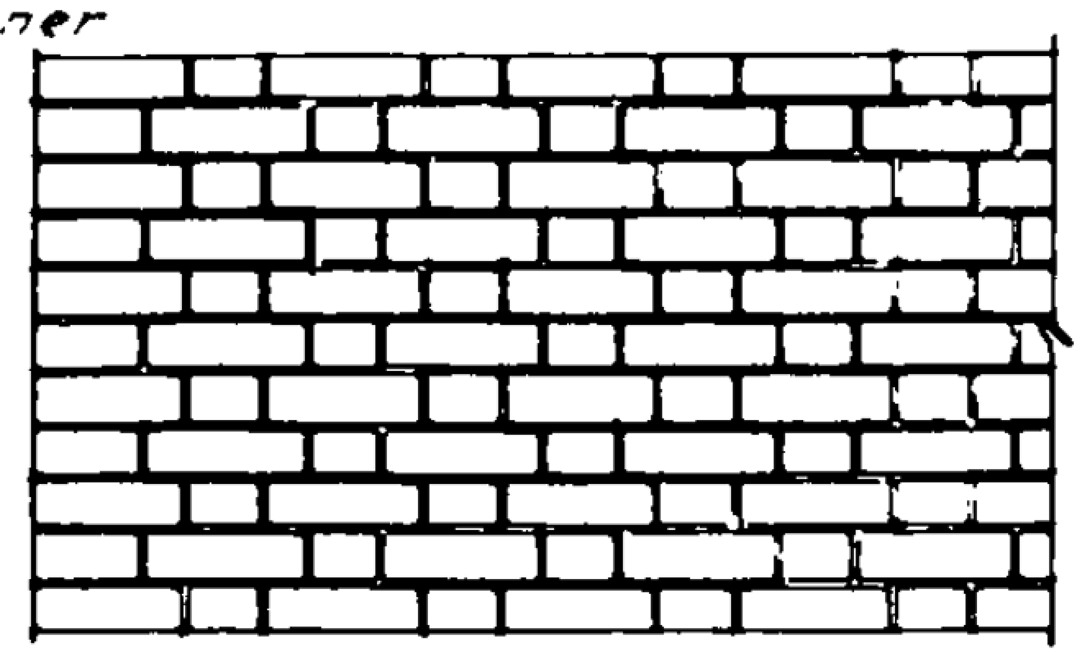
COMMON (Flemish Bond)



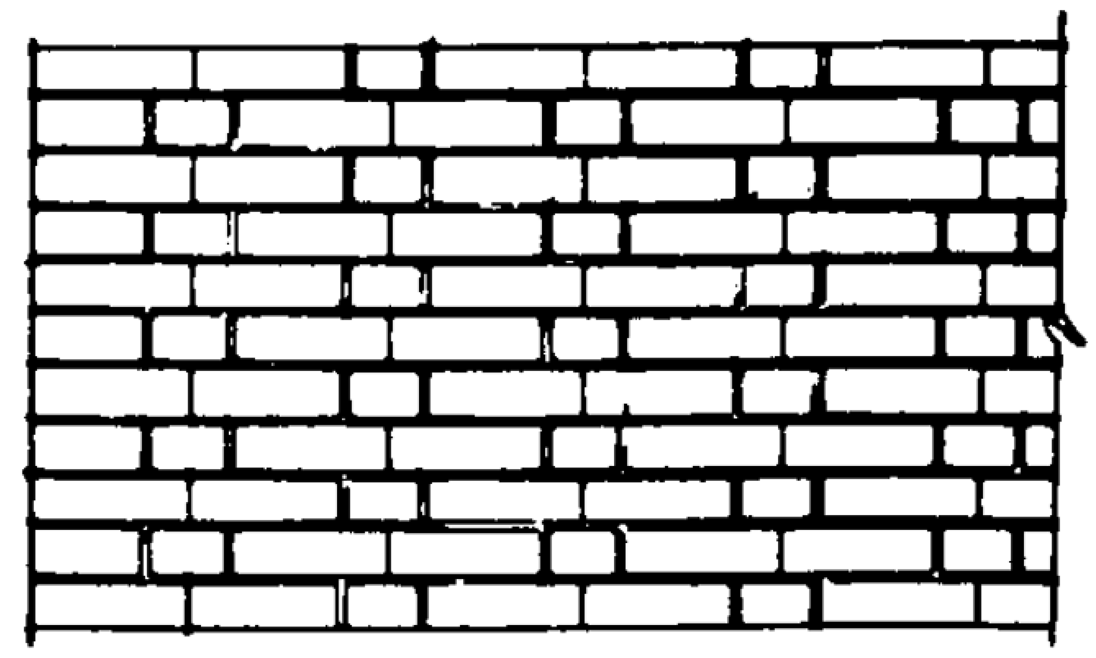
ENGLISH



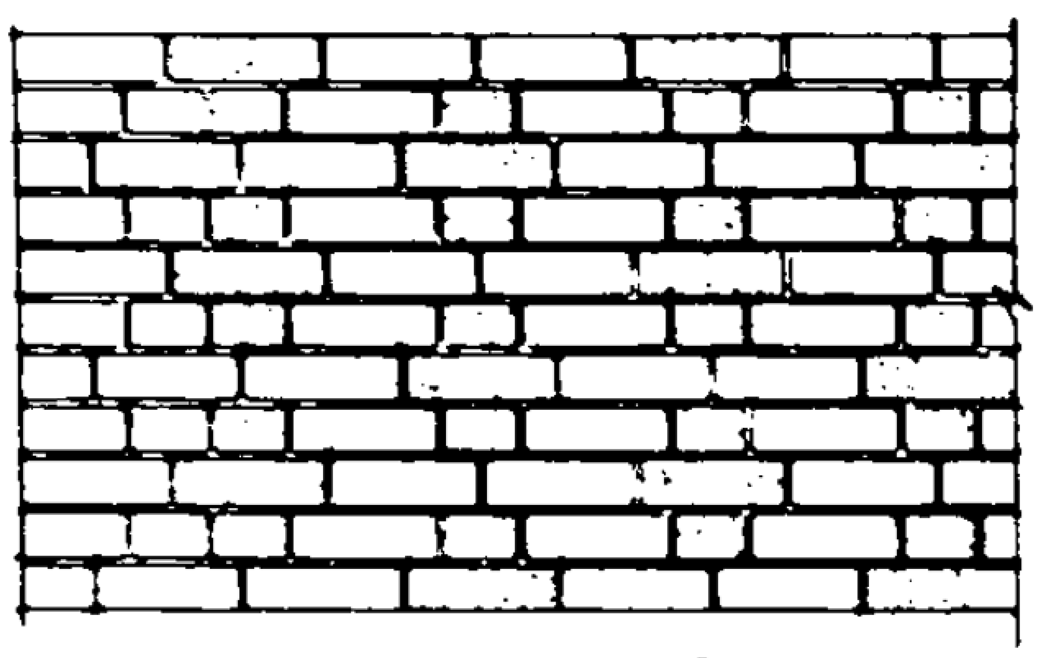
ENGLISH (Cross)



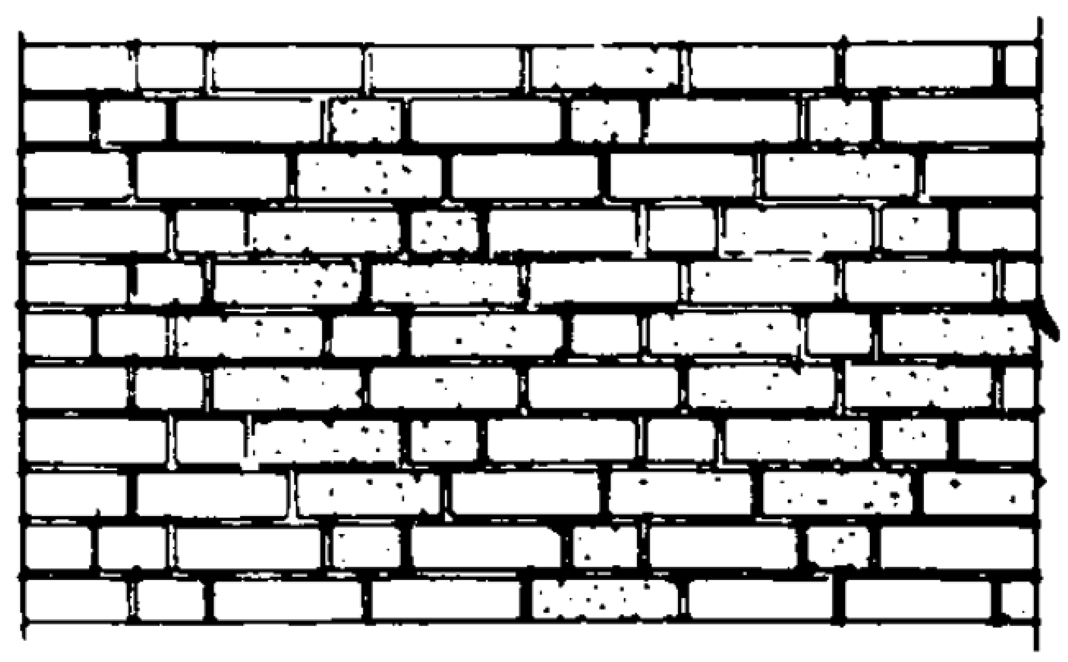
FLEMISH



FLEMISH (Double Stretcher)



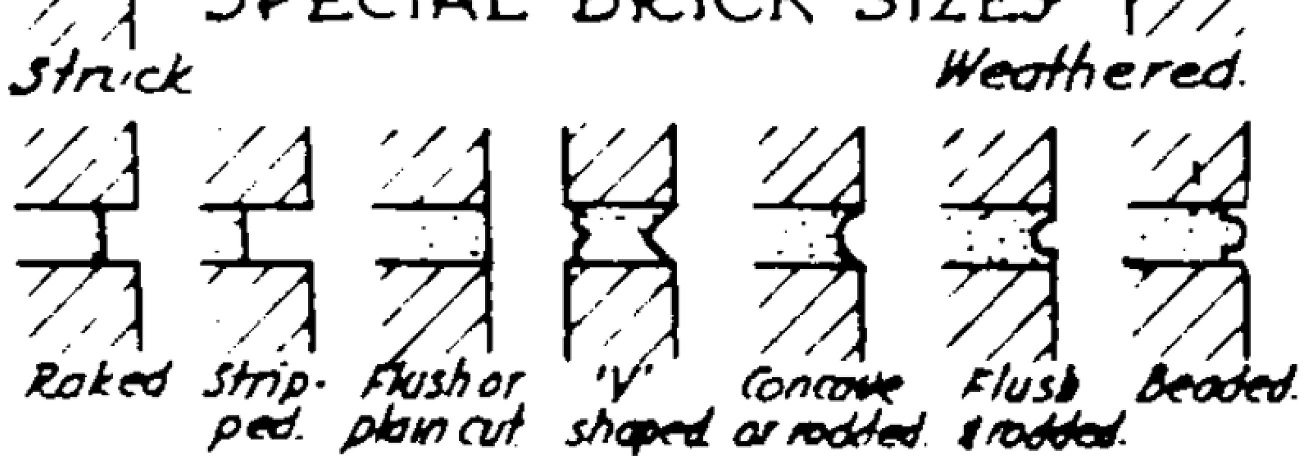
FLEMISH (Cross)



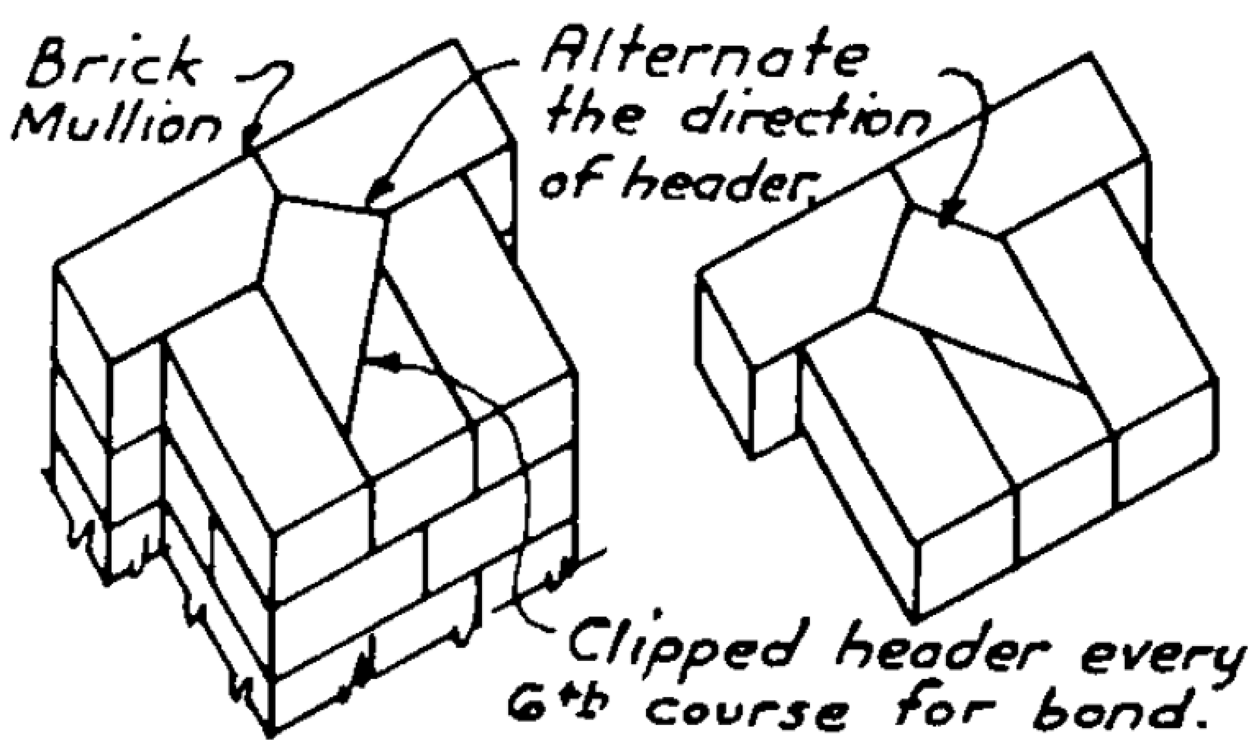
FLEMISH (Diagonal)

Norman: 12" length × 2¼" × 3¾"
Roman: 12" length × 1⅝" × 3¾"
Baby Roman - 8" × 1⅝" × 3¾"
Two Brick Type 5" high × 8" × 3¾"

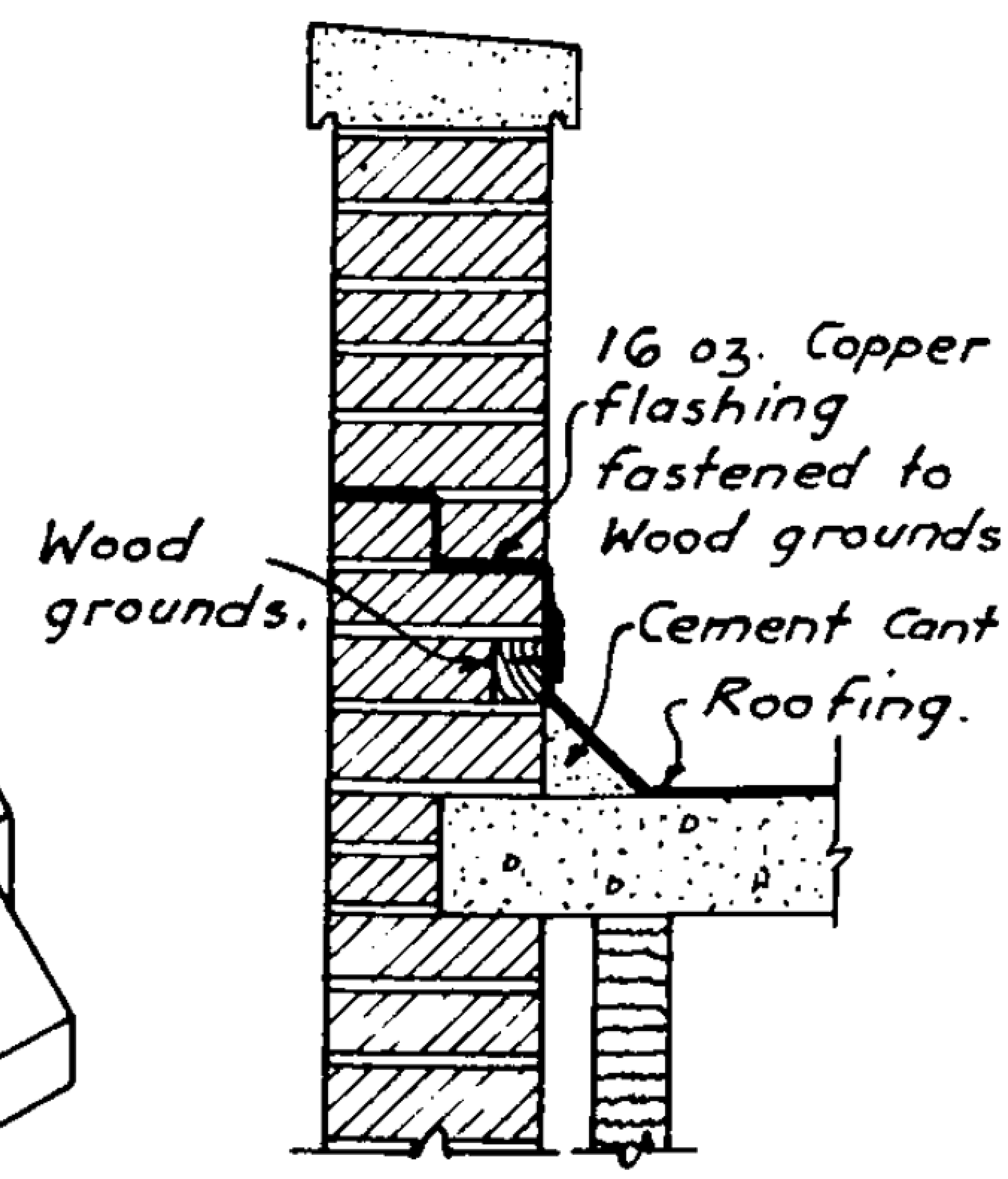
SPECIAL BRICK SIZES



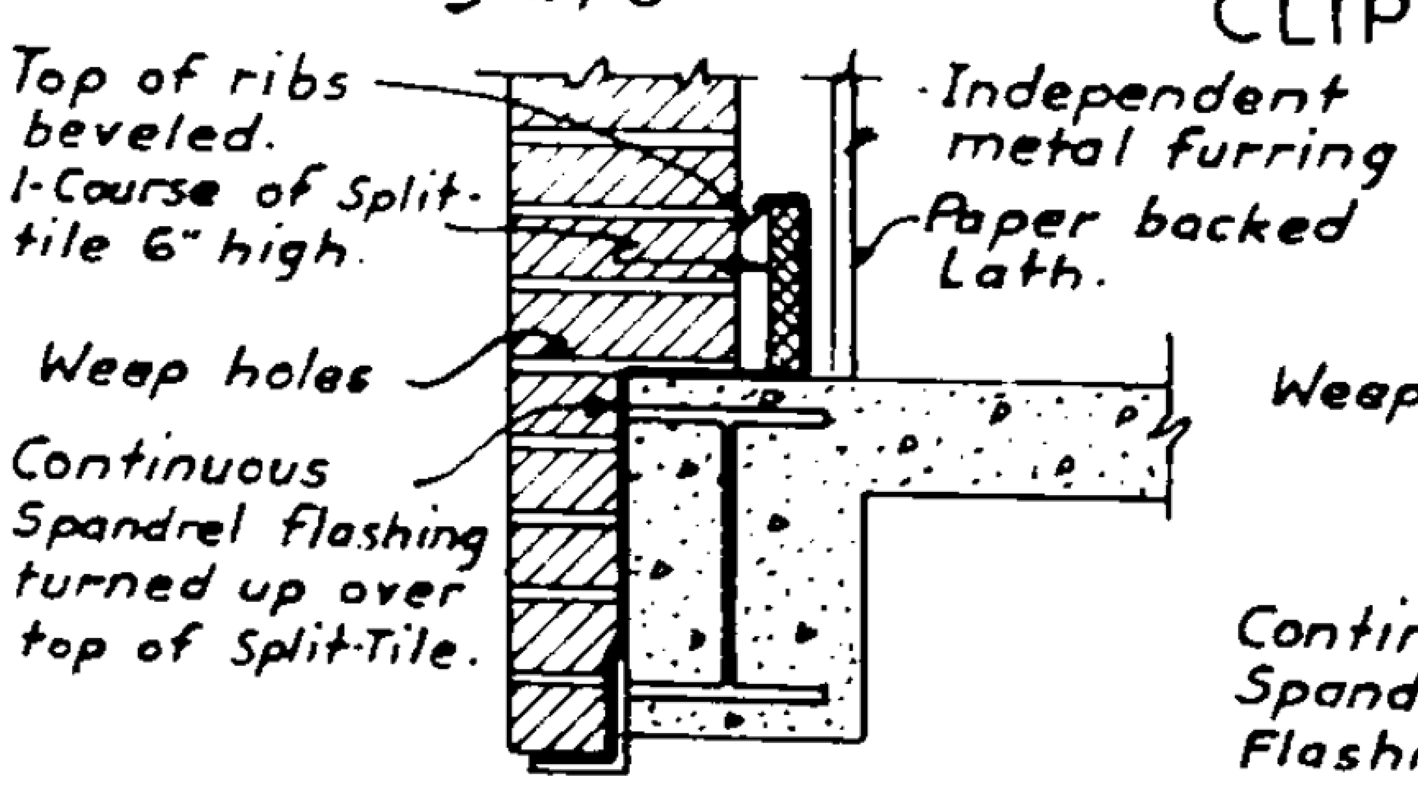
BRICK JOINTS
3" = 1'-0"



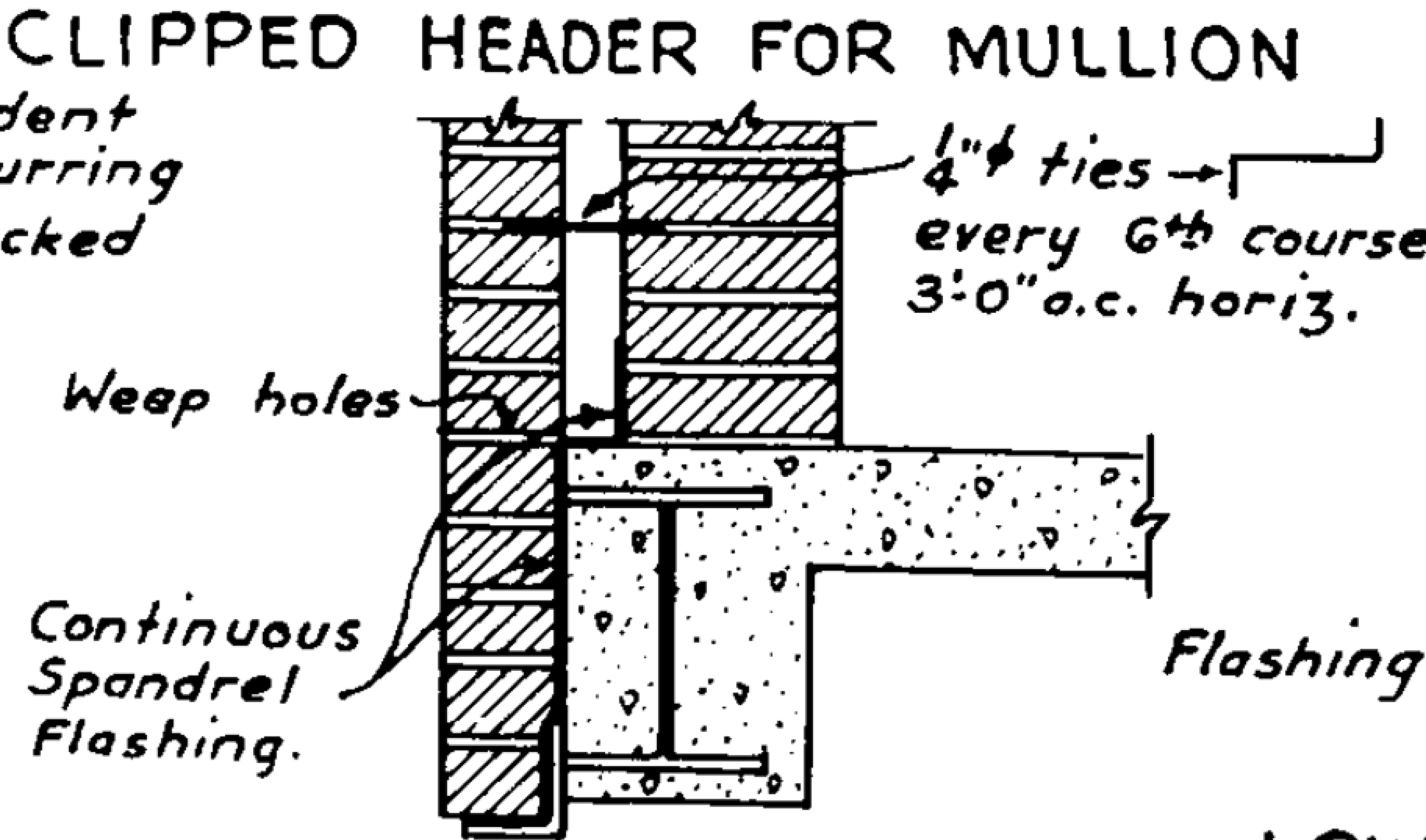
CLIPPED HEADER FOR MULLION



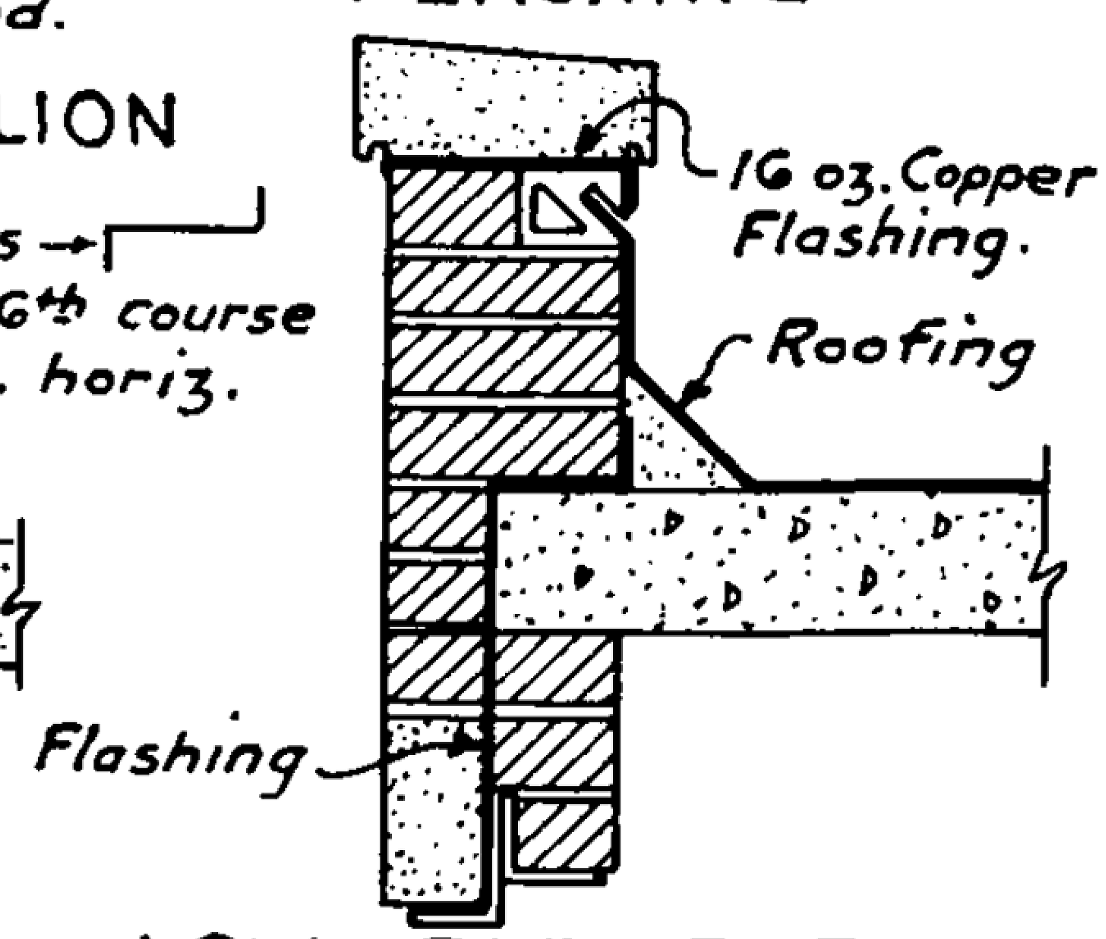
HIGH PARAPET FLASHING



WEATHERPROOF WALL ASSEMBLY



CAVITY WALL

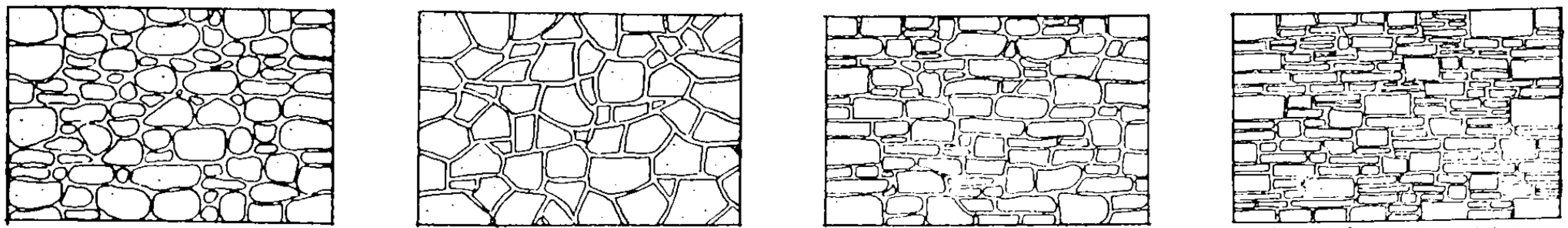


LOW PARAPET FLASHING

Bonds and Joints adapted from Arch. Graphic Stds. by Ramsey & Sleeper.

STRUCTURAL - STONE MASONRY

- STONEWORK -

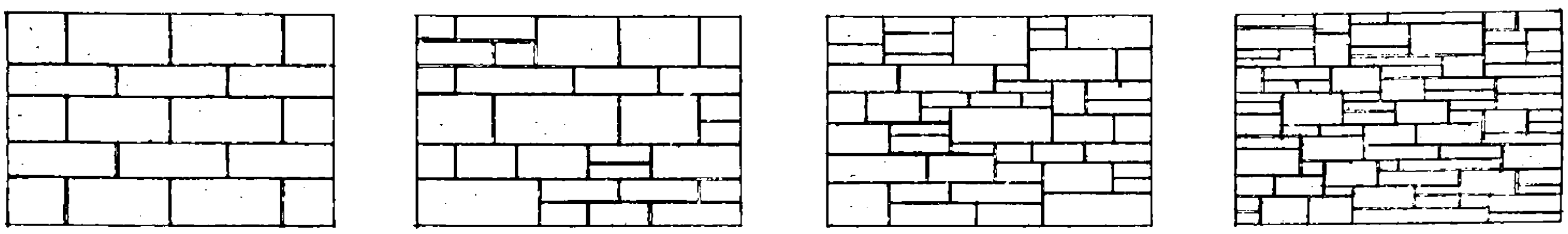


UNCOURSED FIELDSTONE ROUGH OR ORDINARY. — POLYGONAL, MOSAIC OR RANDOM. — COURSED

TYPES OF RUBBLE MASONRY

Laid of stratified stone fitted on job. It is between rubble & ashlar. Finish is quarry face, seam face or split. Called rubble ashlar in granite.

SQUARED-STONE MASONRY.

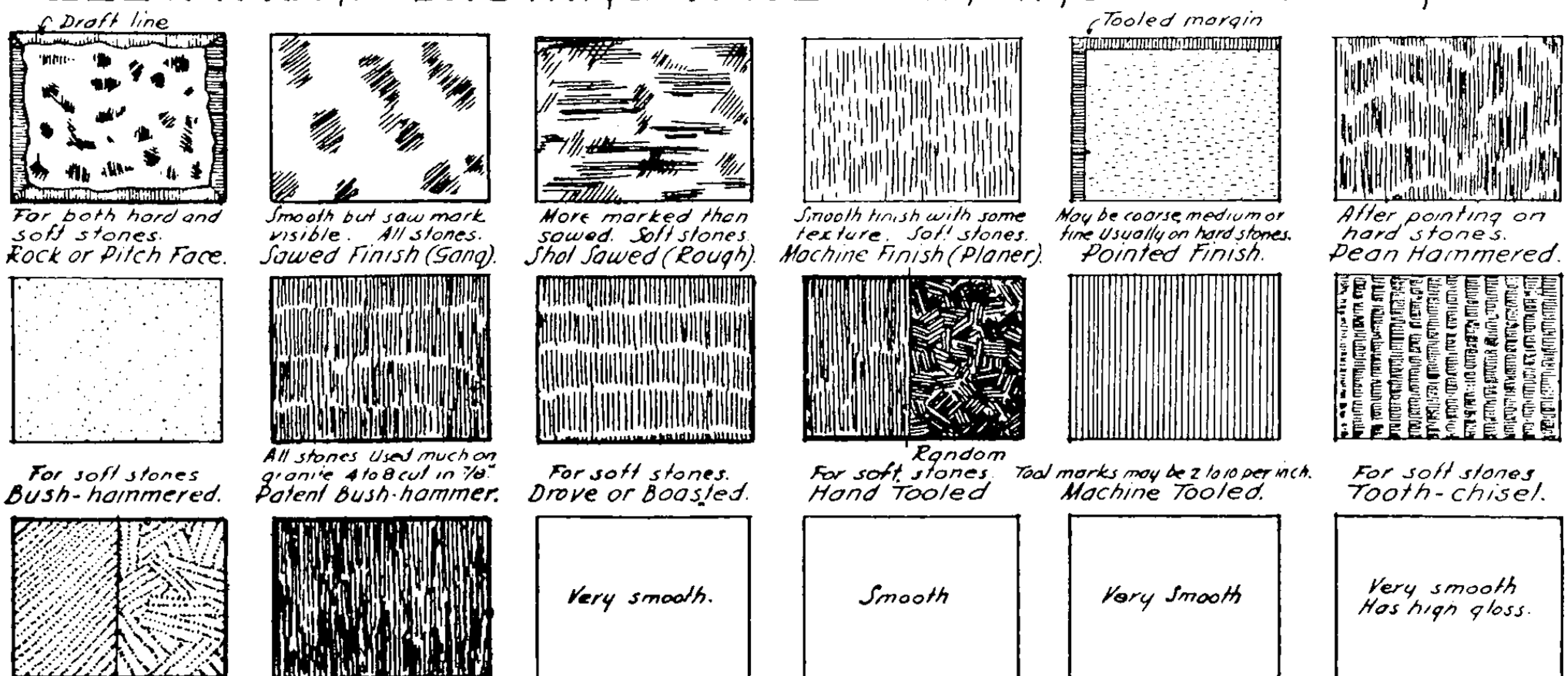


RANGE. *Coursed* — BROKEN RANGE. — RANDOM *Interrupted coursed* — RANGE. *Coursed (Long stones)*

TYPES OF ASHLAR MASONRY

This is stone that is sawed, dressed, squared or Quarry faced.

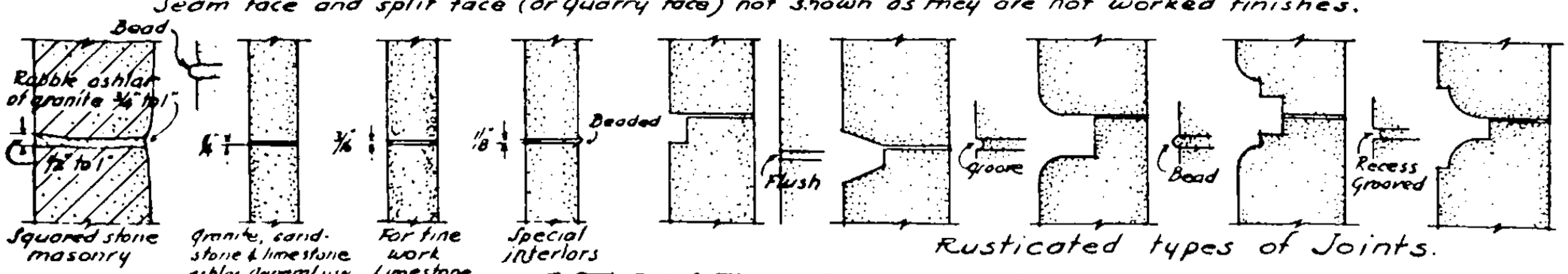
ELEVATIONS SHOWING FACE JOINTING FOR STONE.



- *For both hard and soft stones.* **Rock or Pitch Face.**
- *Smooth but saw mark visible. All stones.* **Sawed Finish (Gang).**
- *More marked than sawed. Soft stones.* **Shot Sawed (Rough).**
- *Smooth finish with some texture. Soft stones.* **Machine Finish (Planer).**
- *May be coarse, medium or fine. Usually on hard stones.* **Pointed Finish.**
- *After pointing on hard stones.* **Pean Hammered.**
- *For soft stones* **Bush-hammered.**
- *All stones. Used much on granite 4 to 8 cut in 7/8".* **Patent Bush-hammer.**
- *For soft stones.* **Drove or Boasted.**
- *For soft stones.* **Hand Tooled**
- *Tool marks may be 2 to 10 per inch.* **Machine Tooled.**
- *For soft stones* **Tooth-chisel.**
- *For soft stones.* **Crandalled.**
- *Textured by machine. For Limestone* **Plucker Finish.**
- *For Limestone. Done by machine* **Carborundum Finish**
- *All stones. May use sand or carborundum.* **Rubbed (Wet).**
- *Marble, granite. For interior work. Soft stones.* **Honed (rubbed first).**
- *Marble and Granite.* **Polished (honed first).**

STONE FINISHES.

Seam face and split face (or Quarry face) not shown as they are not worked finishes.



Squared stone masonry — Granite, sand-stone & limestone ashlar. General use. — For fine work Limestone — Special interiors — Rusticated types of Joints.

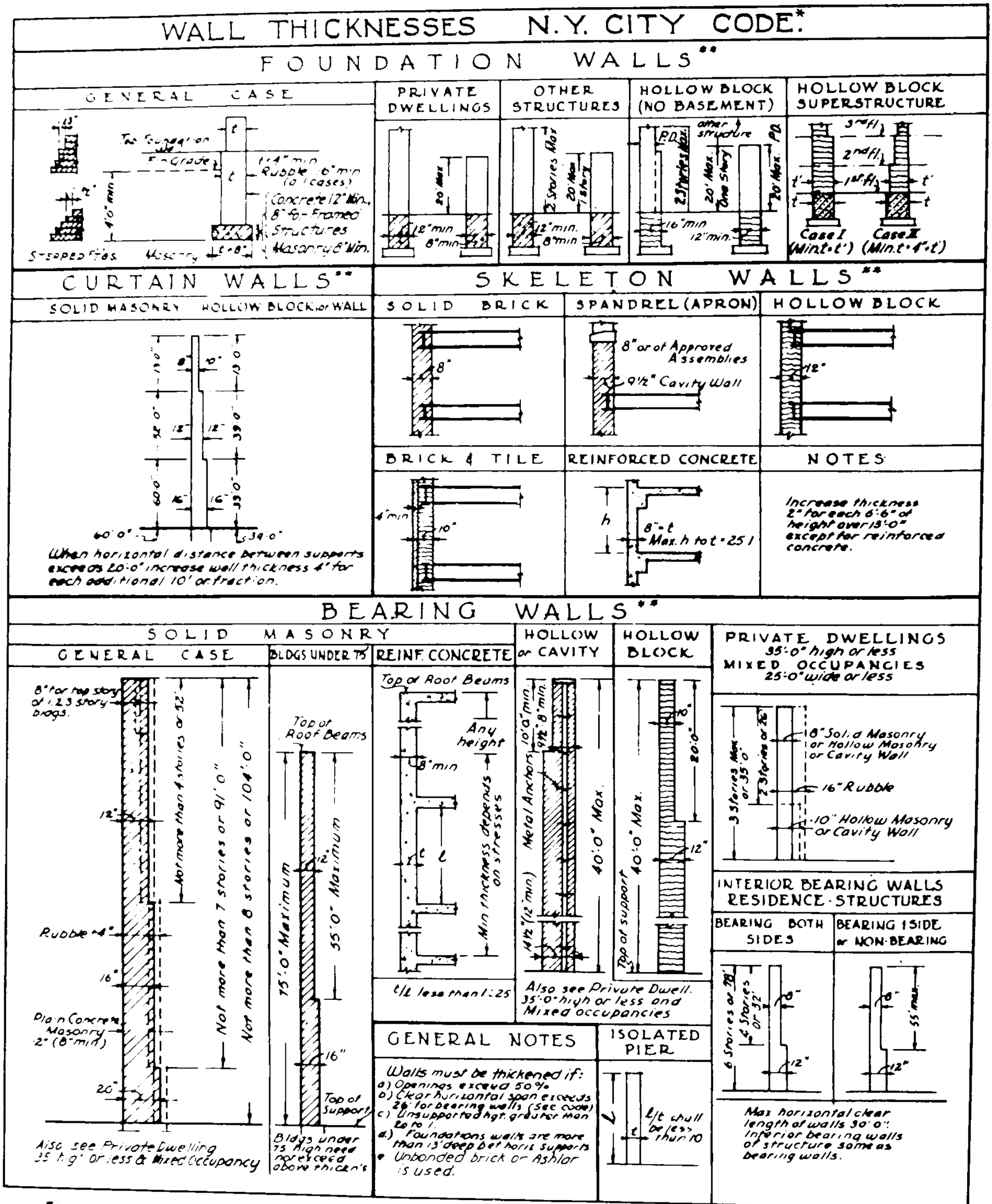
STONE JOINTS

TYPES, FINISH AND JOINTING OF STONE MASONRY.

A perch is nominally 16'6" long, 1'0" high & 1'6" thick = 24¾ cu.ft. In some localities 16½ & 22 cu.ft. are used.

Adapted from Arch. Graphic Stds. by Ramsey & Sleeper.

STRUCTURAL - WALLS

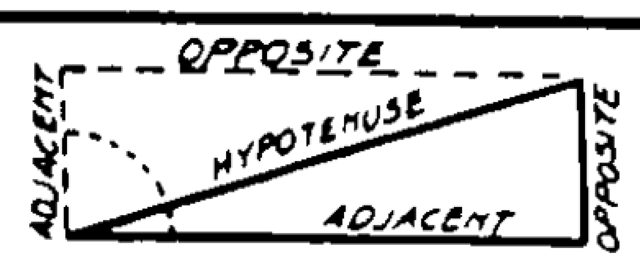


*This Code is incorporated as typical of modern engineering thought of any of the codes. For walls subject to earth pressure - see page 2-69

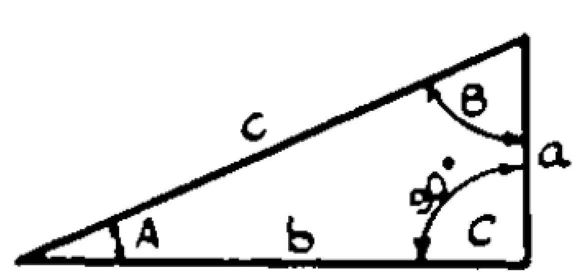
** Compiled by Elwyn E. Seelye.

STRUCTURAL - FORMULAS

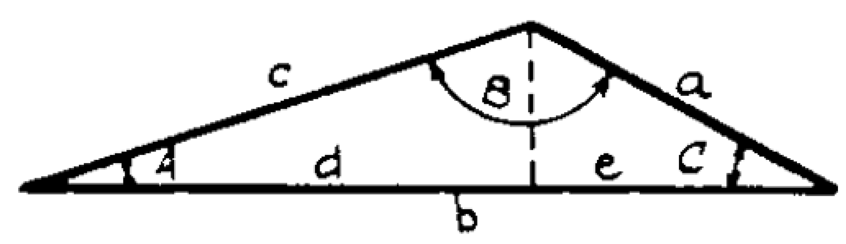
TRIGONOMETRIC FORMULAS.



FUNCTIONS OF ANGLE	OPPOSITE	ADJACENT	HYP
sin = Op ÷ Hyp	Hyp × sin		Op ÷ sin
cos = Ad ÷ Hyp		Hyp × cos	Ad ÷ cos
tan = Op ÷ Ad	Ad × tan	Op ÷ tan	
cot = Ad ÷ Op	Ad ÷ cot	Op × cot	
sec = Hy ÷ Ad		Hyp ÷ sec	Ad × sec
cosec = Hy ÷ Op	Hyp ÷ cosec		Op × cosec



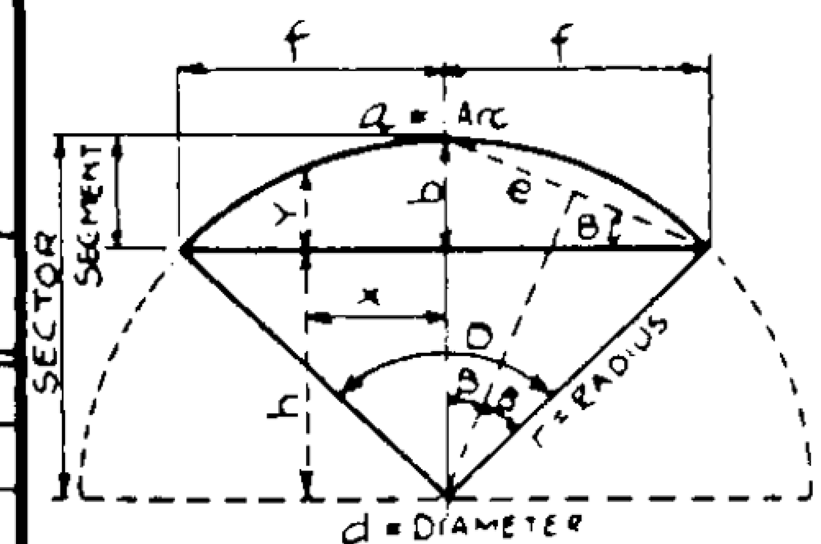
GIVEN	TO FIND	FORMULA	
ab	A	tan = a ÷ b	cot = b ÷ a
	B	cot = a ÷ b	tan = b ÷ a
ac	A	sin = a ÷ c	cosec = c ÷ a
	B	cos = a ÷ c	sec = c ÷ a
bc	A	sec = c ÷ b	cos = b ÷ c
	B	cosec = c ÷ b	sin = b ÷ c
Aa	b	a cot A	a ÷ tan A
	c	a cosec A	a ÷ sin A
Ab	a	b tan A	b ÷ cot A
	c	b sec A	b ÷ cos A
Ac	a	c sin A	c ÷ cosec A
	b	c cos A	c ÷ sec A

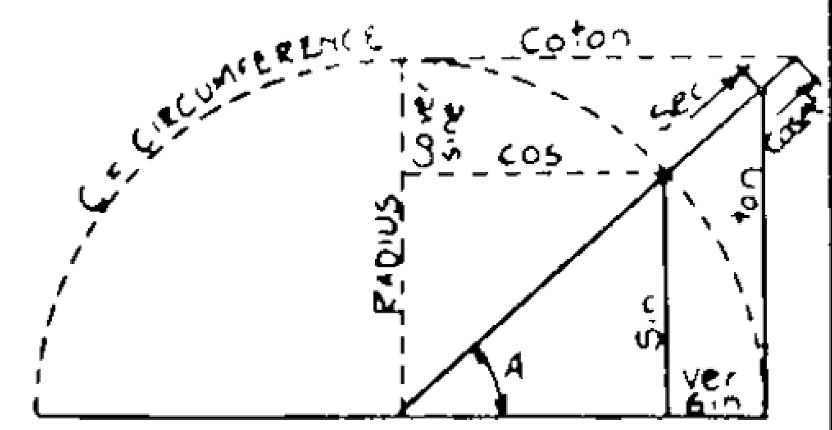


$$S = \frac{a+b+c}{2}$$

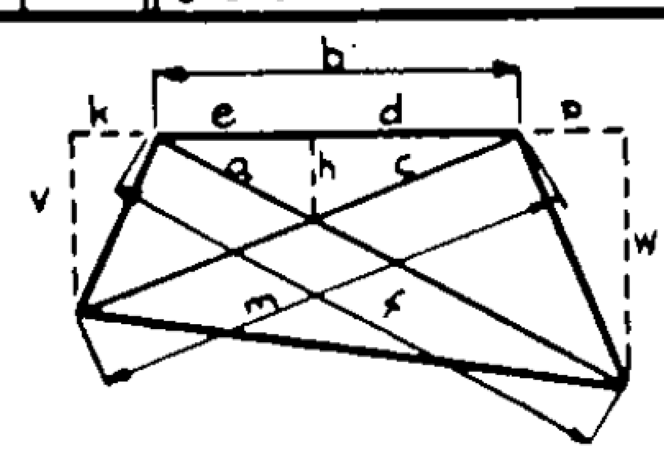
GIVEN	TO FIND	FORMULA
ABa	b	a sin B ÷ sin A
	c	a sin(A+B) ÷ sin A
ABb	a	b sin A ÷ sin B
	c	b sin(A+B) ÷ sin B
ABc	a	c sin A ÷ sin(A+B)
	b	c sin B ÷ sin(A+B)
ACa	b	a sin(A+C) ÷ sin A
	c	a sin C ÷ sin A
ACb	a	b sin A ÷ sin(A+C)
	c	b sin C ÷ sin(A+C)
ACc	a	c sin A ÷ sin C
	b	c sin(A+C) ÷ sin C
BCa	b	a sin B ÷ sin(B+C)
	c	a sin C ÷ sin(B+C)
BCb	a	b sin(B+C) ÷ sin B
	c	b sin C ÷ sin B
BCc	a	c sin(B+C) ÷ sin C
	b	c sin B ÷ sin C
abc	S	(a+b+c) ÷ 2
abcs	A	$\sin \frac{1}{2} A = \sqrt{(s-b)(s-c) \div bc}$
		$\cos \frac{1}{2} A = \sqrt{s(s-a) \div bc}$
		$\tan \frac{1}{2} A = \sqrt{(s-b)(s-c) \div s(s-a)}$
abcs	B	$\sin \frac{1}{2} B = \sqrt{(s-a)(s-c) \div ac}$
		$\cos \frac{1}{2} B = \sqrt{s(s-b) \div ac}$
		$\tan \frac{1}{2} B = \sqrt{(s-a)(s-c) \div s(s-b)}$
abcs	C	$\sin \frac{1}{2} C = \sqrt{(s-a)(s-b) \div ab}$
		$\cos \frac{1}{2} C = \sqrt{s(s-c) \div ab}$

GIVEN	TO FIND	FORMULA
abcs	C	$\tan \frac{1}{2} C = \sqrt{(s-a)(s-b) \div s(s-c)}$
abcs	d	$(b^2+c^2-a^2) \div 2b$
	e	$(a^2+b^2-c^2) \div 2b$
Aab	B	sin = b sin A ÷ a
Aac	C	sin = c sin A ÷ a
Bab	A	sin = a sin B ÷ b
Bbc	C	sin = c sin B ÷ b
Cac	A	sin = a sin C ÷ c
Cbc	B	sin = b sin C ÷ c
Abc	½(B+C)	90° − ½A
	½(B−C)	tan = [(b−c) tan(90° − ½A)] ÷ (b+c)
	B	½(B+C) + ½(B−C)
	C	½(B+C) − ½(B−C)
	a	$\sqrt{b^2+c^2-2bc \cos A}$
Bac	½(A+C)	90° − ½B
	½(A−C)	tan = [(a−c) tan(90° − ½B)] ÷ (a+c)
	A	½(A+C) + ½(A−C)
	C	½(A+C) − ½(A−C)
	b	$\sqrt{a^2+c^2-2ac \cos B}$
Cab	½(A+B)	90° − ½C
	½(A−B)	tan = [(a−b) tan(90° − ½C)] ÷ (a+b)
	A	½(A+B) + ½(A−B)
	B	½(A+B) − ½(A−B)
	c	$\sqrt{a^2+b^2-2ab \cos C}$

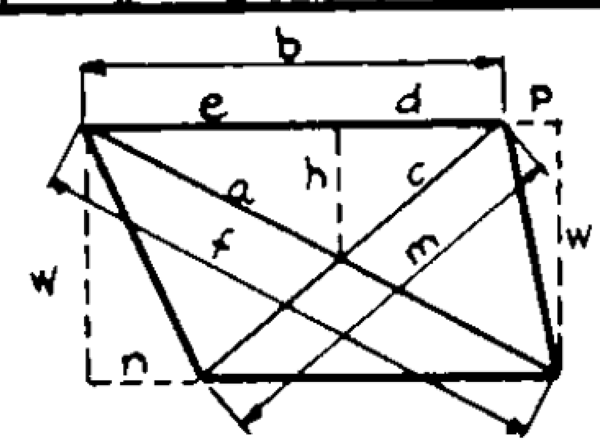




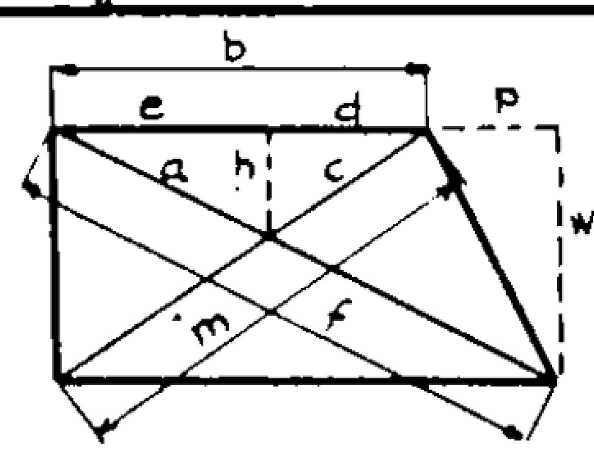
GIVEN	TO FIND	FORMULA
drB	b	$d \sin^2 B$
	f	r sin 2B
	e	d sin B
drb	Ang B	$\sin B = \sqrt{b \div d}$
	f	$\sqrt{b(d-b)}$
	e	$\sqrt{db}$
dre	Ang B	sin B = e ÷ d
	b	$e^2 \div d$
	f	$e\sqrt{d^2-e^2} \div d$
bB	r	$\frac{1}{2} b \div \sin^2 B$
eB	r	½e ÷ sin B
bf	Ang B	tan B = b ÷ f
	r	$(f^2+b^2) \div 2b$
fe	Ang B	$\sin B = \sqrt{e^2-f^2} \div e$
	r	$\frac{1}{2} e^2 \div \sqrt{e^2-f^2}$
be	Ang B	sin B = b ÷ e
	r	$\frac{1}{2} e^2 \div b$
rxy	Ang B	$\cos 2B = (\sqrt{r^2-x^2}-y) \div r$
	b	$r+y-\sqrt{r^2-x^2}$
brx	y	$b+\sqrt{r^2-x^2}-r$
bry	x	$\sqrt{r^2-(r+y-b)^2}$
bxy	r	$[x^2+(b-y)^2] \div (2b-2y)$
r	Circ	6.2832 r
rD	Arc a	.0174533 r D°
	Arc a	.0002909 r D′
	Arc a	.00000485 r D″
r	Area	Circle = 3.1416 r^2
d		" = 0.7854 d^2
c		" = 0.0796 c^2
ar		Sector = 0.5ar
arfh		Segment = 0.5ar − fh



GIVEN	TO FIND	FORMULA
bpw	f	$\sqrt{(b+p)^2+w^2}$
bkv	m	$\sqrt{(b+k)^2+v^2}$
bkp vw	d	bw(b+k) ÷ [v(b+p) + w(b+k)]
	e	bv(b+p) ÷ [v(b+p) + w(b+k)]
bfk pvw	a	fbv ÷ [v(b+p) + w(b+k)]
bkm pvw	c	bmw ÷ [v(b+p) + w(b+k)]
bkpvw	h	bvw ÷ [v(b+p) + w(b+k)]
afw	h	aw ÷ f
cmv	h	cv ÷ m



GIVEN	TO FIND	FORMULA
bpw	f	$\sqrt{(b+p)^2+w^2}$
bnw	m	$\sqrt{(b-n)^2+w^2}$
bnp	d	b(b−n) ÷ (2b+p−n)
	e	b(b+p) ÷ (2b+p−n)
bfnp	a	bf ÷ (2b+p−n)
bmnp	c	bm ÷ (2b+p−n)
bnpw	h	bw ÷ (2b+p−n)
afw	h	aw ÷ f
cmw	h	cw ÷ m



GIVEN	TO FIND	FORMULA
bpw	f	$\sqrt{(b+p)^2+w^2}$
bw	m	$\sqrt{b^2+w^2}$
bp	d	$b^2 \div (2b+p)$
	e	b(b+p) ÷ (2b+p)
bfp	a	bf ÷ (2b+p)
bmp	c	bm ÷ (2b+p)
bpw	h	bw ÷ (2b+p)
afw	h	aw ÷ f
cmw	h	cw ÷ m

Data by American Bridge Co. - from Singleton, Manual of Structural Design, H. M. Ives & Sons.

STRUCTURAL - FORMULAS

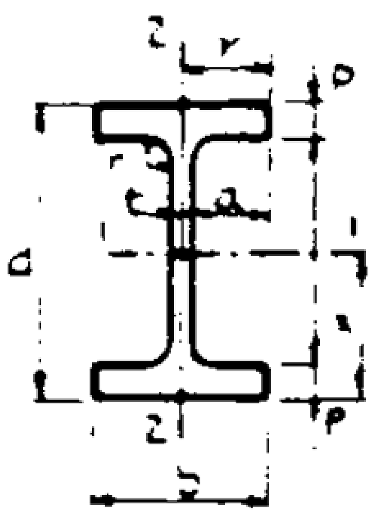
A = Area of Section
I = Moment of Inertia
S = Section Modulus
r = Radius of Gyration
f = Extreme fiber stress p.s.i.
M = Moment in in. lbs.

PROPERTIES OF SECTIONS

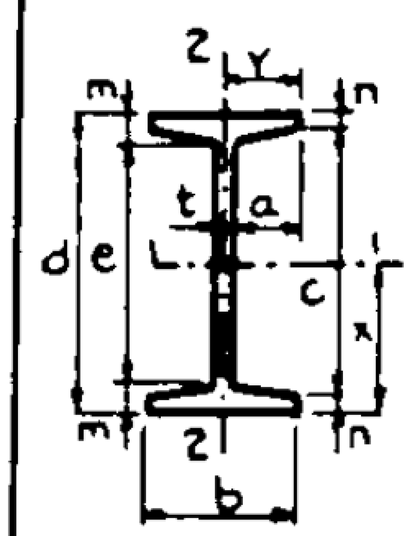
For rolled steel sections:

$$S = \frac{I}{x}$$

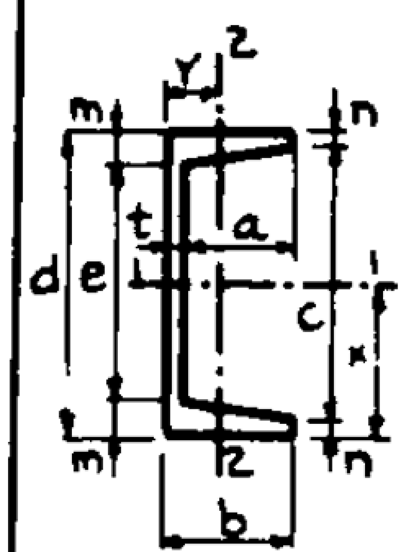
$$r = \sqrt{\frac{I}{A}}$$



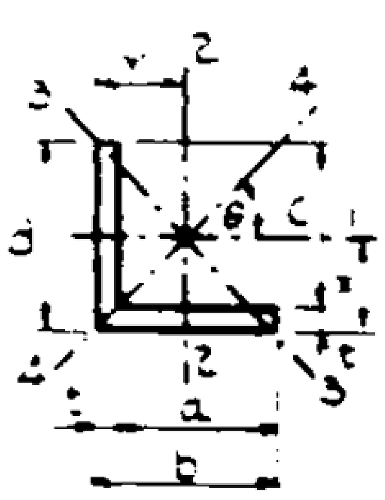
$$A = dt + 4ap + \tfrac{2}{3} r^2$$
$$x = \frac{d}{2}$$
$$y = \frac{b}{2}$$
$$I_1 = \frac{bd^3 - 2ac^3}{12} + 4\left[\frac{11}{200} r^4 + \frac{1}{6} r^2 \left(\frac{c}{2} - \frac{r}{8}\right)^2\right]$$
$$I_2 = \frac{2pb^3 + ct^3}{12} + 4\left[\frac{11}{200} r^4 + \frac{1}{6} r^2 \left(\frac{t}{2} + \frac{r}{8}\right)^2\right]$$



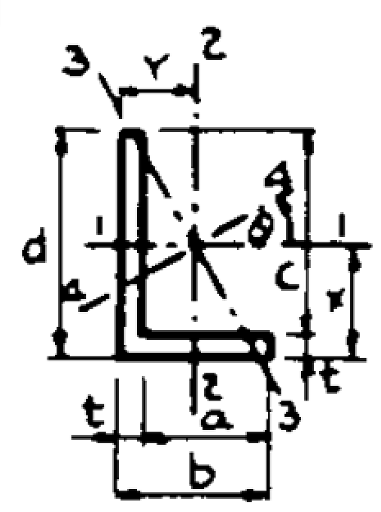
$$A = dt + 2a(m+n)$$
$$x = \frac{d}{2}$$
$$y = \frac{b}{2}$$
$$I_1 = \frac{bd^3 - \frac{a}{4(m-n)}(c^4 - e^4)}{12}$$
$$I_2 = \frac{2nb^3 + et^3 + \frac{m-n}{4a}(b^4 - t^4)}{12}$$



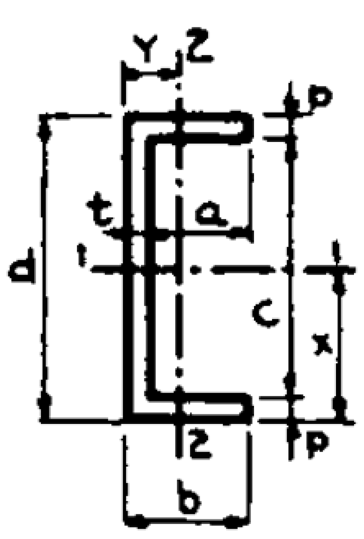
$$A = dt + a(m+n)$$
$$x = \frac{d}{2}$$
$$y = \frac{b^2 n + \frac{ct^2}{2} + \frac{a(m-n)}{3}(b+2t)}{A}$$
$$I_1 = \frac{bd^3 - \frac{a}{8(m-n)}(c^4 - e^4)}{12}$$
$$I_2 = \frac{2nb^3 + et^3 + \frac{(m-n)}{2a}(b^4 - t^4)}{3} - Ay^2$$



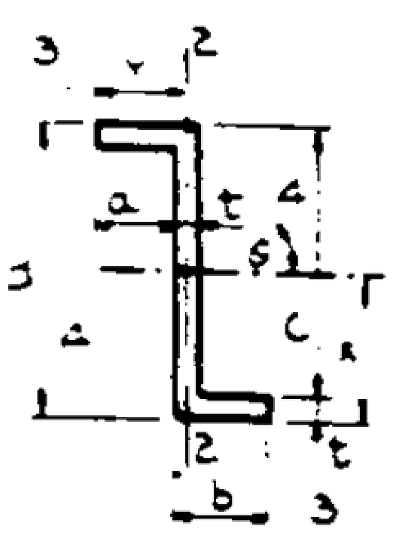
$$A = t(b+c); \qquad \theta = 45^\circ$$
$$x = \frac{b^2 + ct}{2b + c}, \qquad y = x$$
$$I_1 = \frac{t(b-x)^3 + bx^3 - a(x-t)^3}{3}$$
$$I_2 = I_1$$
$$I_3 = \frac{a^3 + c^3 t + 3cd(b - 4 + 2t)^2 + t^4 + 6t^2(x-t)^2}{12}$$
$$I_4 = \frac{ct^3 + c^3 t + 3ctb^2 + t^4}{12}$$



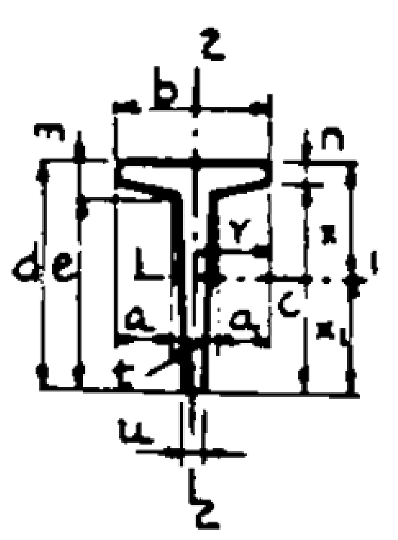
$$A = t(b+c); \quad x = \frac{t(b+2c) + c^2}{2(b+c)}; \quad y = \frac{t(2a+d) + a^2}{2(a+d)}$$
$$\tan 2\theta = \frac{t[(b-t)d(d-2x) + a(a+t)(b+t-2y)]}{2(I_1 - I_2)}$$
$$I_1 = \frac{t(d-x)^3 + bx^3 - a(x-t)^3}{3}$$
$$I_2 = \frac{t(b-y)^3 + dy^3 - c(y-t)^3}{3}$$
$$I_3 = \frac{I_2 \cos^2\theta - I_1 \sin^2\theta}{\cos 2\theta}$$
$$I_4 = \frac{I_1 \cos^2\theta - I_2 \sin^2\theta}{\cos 2\theta}$$



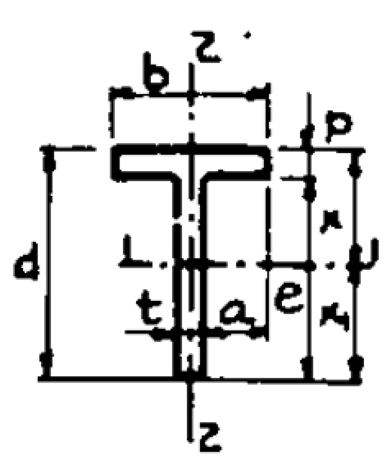
$$A = bd - c(b-t)$$
$$x = \frac{d}{2}$$
$$y = \frac{\frac{t}{2}[b^2 d - c(b-t)^2]}{bd - c(b-t)}$$
$$I_1 = \frac{bd^3 - c^3(b-t)}{12}$$
$$I_2 = \frac{2b^3 p + ct^3}{3} - Ay^2$$



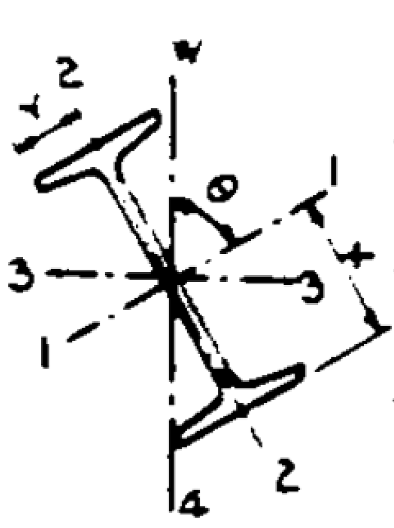
$$A = t(d+2a); \quad x = \frac{d}{2}; \quad y = \frac{2b-t}{2}$$
$$\tan 2\theta = \frac{(dt - t^2)(b^2 - bt)}{I_1 - I_2}$$
$$I_1 = \frac{bd^3 - a(d-2t)^3}{12}$$
$$I_2 = \frac{d(b+a)^3 - 2a^3 t - 6ab^2 t}{12}$$
$$I_3 = \frac{I_2 \cos^2\theta - I_1 \sin^2\theta}{\cos 2\theta}$$
$$I_4 = \frac{I_1 \cos^2\theta - I_2 \sin^2\theta}{\cos 2\theta}$$



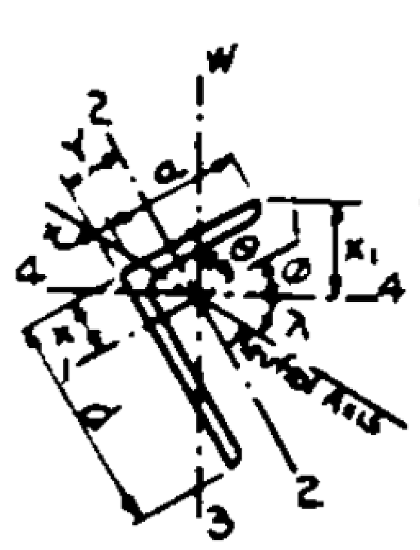
$$A = \frac{e(t+u)}{2} + mt + a(m+n); \quad y = \frac{b}{2}$$
$$x = \frac{6an^2 + 2a(m-n)(m+2n) + 3td^2 - e(t-u)(3d-e)}{6A}$$
$$I_1 = \frac{c^3(3u+t) + 4bm^3 - 2a(m-n)^3}{12} - A(x-m)^2$$
$$I_2 = \frac{nb^3 + (m-n)t^3 + eu^3}{12}$$
$$+ \frac{a(m-n)[2a^2 + (2a+3t)^2]}{36}$$
$$+ \frac{e(t-u)[(t-u)^2 + 2(t+2u)^2]}{144}$$



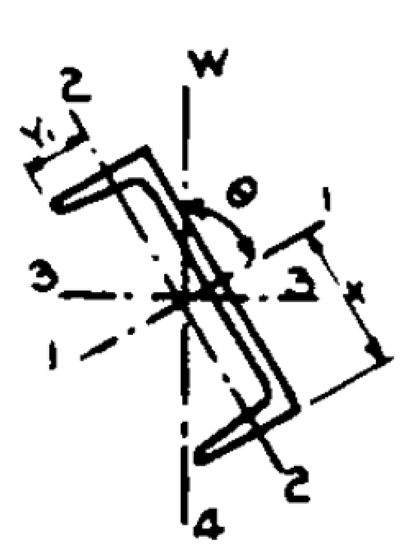
$$A = bp + et; \qquad x_1 = d - x$$
$$x = \frac{d^2 t + p^2(b-t)}{2A}; \qquad y = \frac{b}{2}$$
$$I_1 = \frac{tx_1^3 + bx^3 - (b-t)(x-p)^3}{3}$$
$$I_2 = \frac{pb^3 + ct^3}{12}$$



$$I_3 = I_1 \sin^2\theta + I_2 \cos^2\theta$$
$$I_4 = I_1 \cos^2\theta + I_2 \sin^2\theta$$
$$f = M\left(\frac{x}{I_1}\sin\theta + \frac{y}{I_2}\cos\theta\right)$$



$$\tan 2\theta = \frac{2J}{I_2 - I_1}$$
$$J = \frac{t[d(2y-t)(d-2x) + a(2x-t)(a+2t-2y)]}{4}$$
$$I_3 = I_2 - J\tan\theta; \quad I_4 = I_1 + J\tan\theta$$
$$\tan\lambda = \frac{x_1}{y_1} = \frac{I_4}{I_3}\cot\theta$$
$$f = M\left(\frac{x_1}{I_4}\sin\theta + \frac{y_1}{I_3}\cos\theta\right)$$



$$I_3 = I_1 \sin^2\theta + I_2 \cos^2\theta$$
$$I_4 = I_1 \cos^2\theta + I_2 \sin^2\theta$$
$$f = M\left(\frac{x}{I_1}\sin\theta + \frac{y_1}{I_2}\cos\theta\right)$$

* Adapted from Singleton, Manual of Structural Design, H.M. Ives & Sons.

STRUCTURAL-FORMULAS

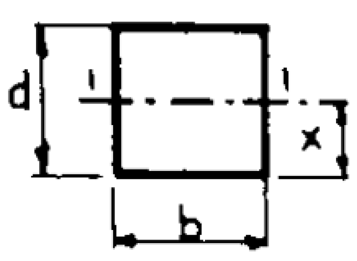
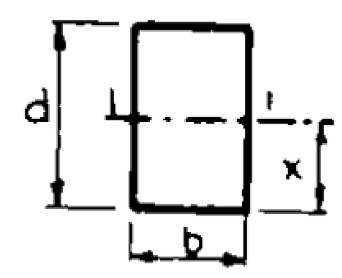
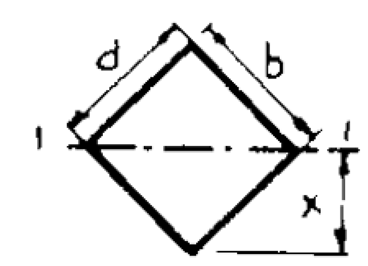
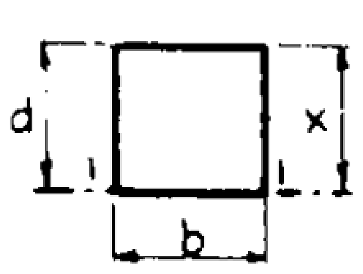
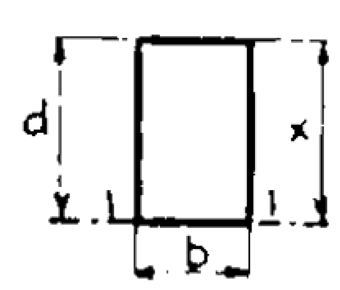
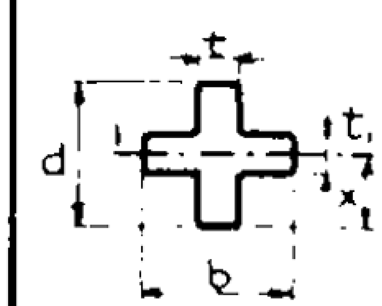
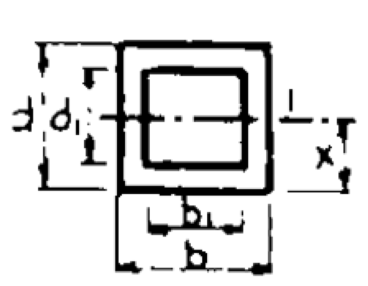
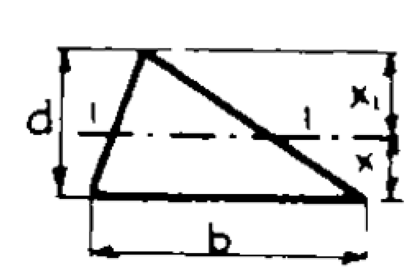
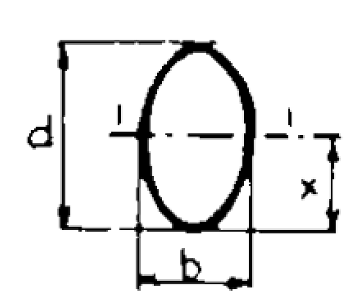
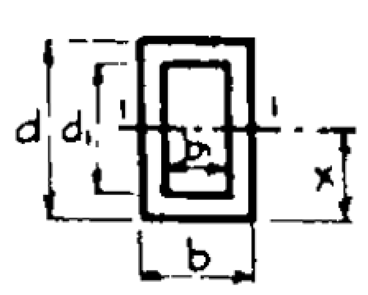
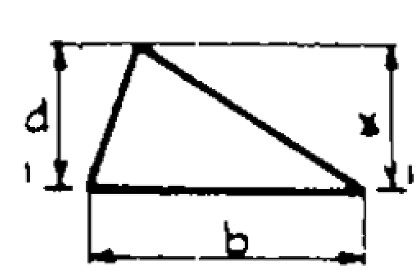
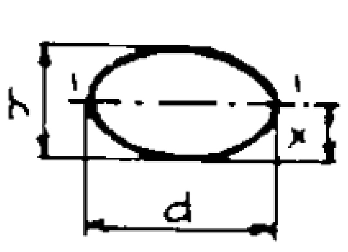
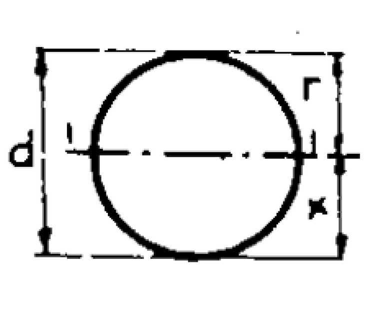
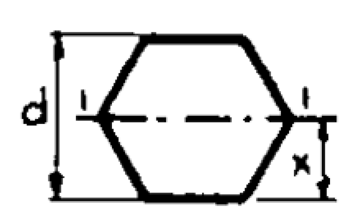
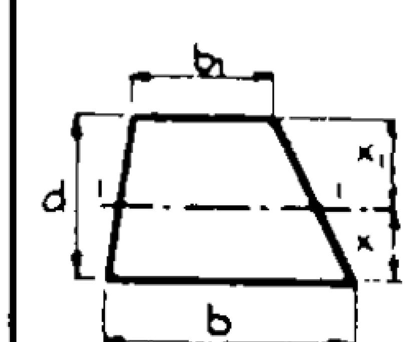
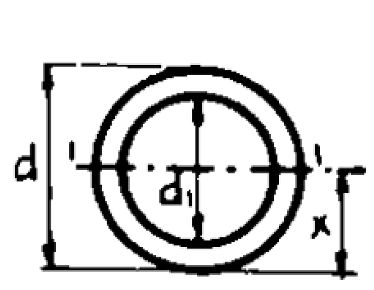
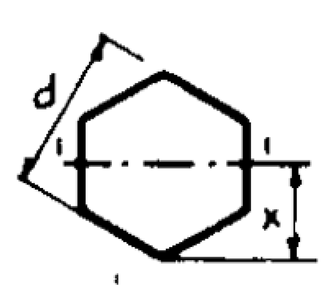
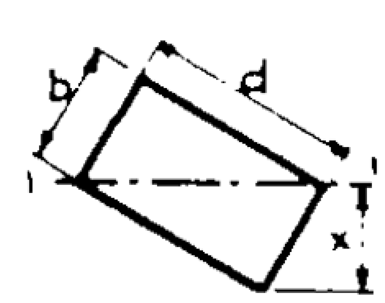
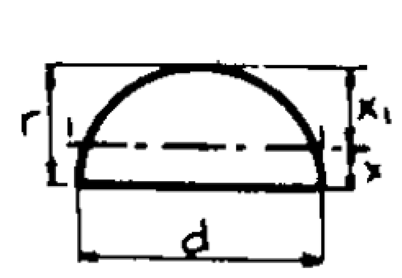
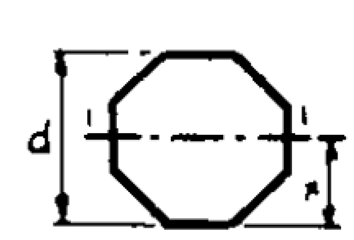
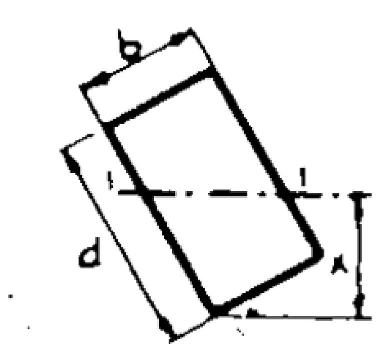
A = Area of Section
I = Moment of Inertia
S = Section Modulus
r = Radius of Gyration

PROPERTIES OF SECTIONS

For rolled steel sections:

$S = \frac{I}{x}$

$r = \sqrt{\frac{I}{A}}$

 $A = d^2$; $x = \frac{d}{2}$ $I_1 = \frac{d^4}{12}$; $S_1 = \frac{d^3}{6}$ $r_1 = \frac{d}{\sqrt{12}} = 0.288675d$	 $A = bd$; $x = \frac{d}{2}$ $I_1 = \frac{bd^3}{12}$; $S_1 = \frac{bd^2}{6}$ $r_1 = \frac{d}{\sqrt{12}} = 0.288675d$	 $A = d^2$, $x = \frac{d}{\sqrt{2}} = 0.707107d$ $I_1 = \frac{d^4}{12}$ $S_1 = \frac{d^3}{6\sqrt{2}} = 0.117851d^3$ $r_1 = \frac{d}{\sqrt{12}} = 0.288675d$
 $A = d^2$; $x = d$ $I_1 = \frac{d^4}{3}$; $S_1 = \frac{d^3}{3}$ $r_1 = \frac{d}{\sqrt{3}} = 0.57735d$	 $A = bd$, $x = d$ $I_1 = \frac{bd^3}{3}$; $S_1 = \frac{bd^2}{3}$ $r_1 = \frac{d}{\sqrt{3}} = 0.57735d$	 $A = td + t_1(b-t)$ $x = \frac{d}{2}$ $I_1 = \frac{td^3 + t_1^3(b-t)}{12}$ $S_1 = \frac{td^3 + t_1^3(b-t)}{6d}$
 $A = d^2 - d_1^2$; $x = \frac{d}{2}$ $I_1 = \frac{d^4 - d_1^4}{12}$; $S_1 = \frac{d^4 - d_1^4}{6d}$ $r_1 = \sqrt{\frac{d^2 + d_1^2}{12}}$	 $A = \frac{bd}{2}$; $x = \frac{d}{3}$; $x_1 = \frac{2d}{3}$ $I_1 = \frac{bd^3}{36}$; $S_1 = \frac{bd^2}{24}$ $r_1 = \frac{d}{\sqrt{18}} = 0.236702d$	 $A = \frac{\pi bd}{4} = .7854bd$, $x = \frac{d}{2}$ $I_1 = \frac{\pi bd^3}{64} = 0.04909bd^3$ $S_1 = \frac{\pi bd^2}{32} = 0.09818bd^2$ $r_1 = \frac{d}{4}$
 $A = bd - b_1d_1$; $x = \frac{d}{2}$ $I_1 = \frac{bd^3 - b_1d_1^3}{12}$; $S_1 = \frac{bd^3 - b_1d_1^3}{6d}$ $r_1 = \sqrt{\frac{bd^3 - b_1d_1^3}{12A}}$	 $A = \frac{bd}{2}$, $x = d$ $I_1 = \frac{bd^3}{12}$; $S_1 = \frac{bd^2}{12}$ $r_1 = \frac{d}{\sqrt{6}} = 0.408248d$	 $A = \frac{\pi bd}{4} = .7854bd$, $x = \frac{b}{2}$ $I_1 = \frac{\pi db^3}{64} = 0.04909db^3$ $S_1 = \frac{\pi db^2}{32} = 0.09818db^2$ $r_1 = \frac{b}{4}$
 $A = \frac{\pi d^2}{4} = \pi r^2 = 0.7854d^2 = 3.14159r^2$ $x = d \div 2 = r$ $I_1 = \frac{\pi d^4}{64} = \frac{\pi r^4}{4} = .04909d^4 = .7854r^4$ $S_1 = \frac{\pi d^3}{32} = \frac{\pi r^3}{4} = .09818d^3 = .7854r^3$ $r_1 = \frac{d}{4} = \frac{r}{2}$	 $A = \frac{3}{2}d^2 \tan 30° = .866d^2$; $x = \frac{d}{2}$ $I_1 = \frac{A}{12}\left[\frac{d^2(1+2\cos^2 30°)}{4\cos^2 30°}\right] = .06d^4$ $S_1 = \frac{A}{6}\left[\frac{d(1+2\cos^2 30°)}{4\cos^2 30°}\right] = .12d^3$ $r_1 = \frac{d}{4}\sqrt{\frac{1+2\cos^2 30°}{3\cos^2 30°}} = .264d$	 $A = \frac{d(b+b_1)}{2}$ $x = \frac{d(b+2b_1)}{3(b+b_1)}$; $x_1 = \frac{d(b_1+2b)}{3(b+b_1)}$ $I_1 = \frac{d^3(b^2+4bb_1+b_1^2)}{36(b+b_1)}$ $S_1 = \frac{d^2(b^2+4bb_1+b_1^2)}{12(b_1+2b)}$ $r_1 = \frac{d}{6(b+b_1)}\sqrt{2(b^2+4bb_1+b_1^2)}$
 $A = \frac{\pi(d^2-d_1^2)}{4}$; $x = \frac{d}{2}$ $I_1 = \frac{\pi(d^4-d_1^4)}{64}$ $S_1 = \frac{\pi(d^4-d_1^4)}{32d}$ $r_1 = \frac{\sqrt{d^2+d_1^2}}{4}$	 $A = \frac{3}{2}d^2 \tan 30°$; $x = \frac{d}{2\cos 30°} = .577d$ $I_1 = \frac{A}{12}\left[\frac{d^2(1+2\cos^2 30°)}{4\cos^2 30°}\right] = .06d^4$ $S_1 = \frac{A}{6}\left[\frac{d(1+2\cos^2 30°)}{4\cos 30°}\right] = .104d^3$ $r_1 = \frac{d}{4}\sqrt{\frac{1+2\cos^2 30°}{3\cos^2 30°}} = .264d$	 $A = bd$; $x = \frac{bd}{\sqrt{b^2+d^2}}$ $I_1 = \frac{b^3d^3}{6(b^2+d^2)}$ $S_1 = \frac{b^2d^2}{6\sqrt{b^2+d^2}}$ $r_1 = \frac{bd}{\sqrt{6(b^2+d^2)}}$
 $A = \frac{\pi r^2}{2} = 1.5708r^2$; $x = \frac{4r}{3\pi}$ $x_1 = r(1-\frac{4}{3\pi}) = 0.57559r$ $I_1 = r^4(\frac{\pi}{8} - \frac{8}{9\pi}) = 0.10976r^4$ $S_1 = \frac{r^3}{24}\frac{(9\pi^2-64)}{(3\pi-4)} = 0.19069r^3$ $r_1 = r\frac{\sqrt{9\pi^2-64}}{6\pi} = 0.26434r$	 $A = 2d^2 \tan 22\tfrac{1}{2}° = 0.828d^2$; $x = \frac{d}{2}$ $I_1 = \frac{A}{12}\left[\frac{d^2(1+2\cos^2 22\frac{1}{2}°)}{4\cos^2 22\frac{1}{2}°}\right] = .055d^4$ $S_1 = \frac{A}{6}\left[\frac{d(1+2\cos^2 22\frac{1}{2}°)}{4\cos^2 22\frac{1}{2}°}\right] = .109d^3$ $r_1 = \sqrt{\frac{1+2\cos^2 22\frac{1}{2}°}{3\cos^2 22\frac{1}{2}°}} = .257d$	 $A = bd$, $x = \frac{b\sin\theta + d\cos\theta}{2}$ $I_1 = \frac{bd(b^2\sin^2\theta + d^2\cos^2\theta)}{12}$ $S_1 = \frac{bd(b^2\sin^2\theta + d^2\cos^2\theta)}{6(b\sin\theta + d\cos\theta)}$ $r_1 = \sqrt{\frac{b^2\sin^2\theta + d^2\cos^2\theta}{12}}$

** Adapted from Singleton, Manual of Structural Design, H. M. Ives & Sons.*

STRUCTURAL – FIREPROOFING REQUIREMENTS

FIREPROOFING REQUIREMENTS

UNDERWRITERS' RECOMMENDATIONS

PROTECTION OF STRUCTURAL PARTS

MEMBER	FIREPROOFING MATERIAL	Minimum Thickness in Inches for hourly Fire Resistive Periods: 4	3	2	1
Steel or Cast Iron Columns	Concrete	3	2	1½	1
	Gunite	2	1½	1	¾
	Brick, of clay, shale or conc	4	4	2½	2½
	Clay Tile, or clay tile and conc	4	3	2	2
	Solid gypsum block; poured gyp	3	3	2	1½
	Hollow gypsum block	3	3	2	2
	Metal lath and gypsum or Portland cement plaster	3 *	2½ *	2	1
Webs and flanges of steel beams and girders, except secondary members; chords and primary members of trusses.	Concrete	2	1½	1	1
	Gunite	2	1	¾	¾
	Brick, of clay, shale or conc	4	2½	2½	2½
	Clay Tile, or clay tile and conc	3	2	1½	¾
	Solid gypsum block; poured gyp	2	2	1½	1
	Hollow gypsum block	3	3	3	3
	Metal lath and gypsum or Portland cement plaster	2½ *	2 *	1½	¾
Reinforced concrete columns and soffits of beams and girders.	Concrete	2	1½	1	1
Soffits of joist and sides of beams and girders, R. C.	Concrete	1½	1	1	¾
Flat ceiling under steel joist or other secondary beams with 2" minimum slab over; all secondary truss members.	Metal or wire lath and gypsum plaster, concrete, burned clay or gypsum	2 *	1½ *	1	¾
	Gunite	1½	1	¾	¾
Reinforcing and tie rods in floor and roof slabs.	Concrete	1	1	¾	¾
	Gypsum	1¼	1	1	¾
Wood joist with double board floor on top of joist.	Metal or wire lath with gypsum cement plaster	....	....	...	¾

*For this table indicates 2 equal layers of plaster with 1" air space.

FIRE-RESISTANCE RATING OF WALLS

MATERIAL	CONSTRUCTION	Minimum Thickness finished, inches, for Fire Resistive Periods: 4	3	2	1
Brick of Clay Shale or Concrete	Solid, unplastered	8	8	8	*4
	Solid, plastered	9	9	*5	*5
	Hollow (rowlock), unplastered	12	12	8	8
	Hollow (rowlock), plast'd	9	9	9	9
Structural Clay or Shale Tile	End or side construction. One cell in wall thickness, plastered	..	....	7	*4
	End or side construction. Two cells in 6" or 8" thickness, unplastered	16	16	12	*6
	End or side construction. Two cells in 6" or 8" thickness, plastered	13	13	*7 9	*5 9
	End or side construction. Three cells in 8" thickness. Unplastered	16	12	12	8
	End or side construction. Three cells in 8" thickness. Plastered	13	13	9	9
Hollow Concrete Blocks	One cell in 8" or less thickness. Unplastered	12	10	8	
	One cell in 8" or less thickness. Plastered	11	9	*7 9	*7 9
Solid Concrete Solid Gunite	Reinforcement not less than 0.2% in each direction.	6 *5	*4 *3½	*3 *2½	*2 *1½
Hollow Gypsum Blocks	Plastered or unplastered	*6	*5	*4	*3
Hollow Gunite Wall	Hollow, reinforced. Outer shell 2" thick for 10" wall or 1½" for 8" wall	10	8		
Solid Gypsum or Portland Cem. Plaster	Incombustible studding with metal or wire lath	..	....	*3	*2
Hollow partition with ¾" gypsum or cement plaster, or Gunite on each side	Incombustible studs, metal or wire lath. 1" plaster for 2 hr. rate	..	....	*4	*3
	Wood studs, metal or wire lath. Fire stopped	..	....	....	*3 5

*For this table indicates walls are non-bearing.

FIREPROOFING. Where flat ceilings are suspended to form an air space between the member and the protection, the permissible ceiling thickness may be ½" less than shown in table, with a minimum of ¾". The fireproofing of iron or steel members shall be measured outside of the extreme edges of the member, except that projecting lugs or brackets shall have a minimum of 1" thickness. For reinforced concrete members the thickness called for in table shall be outside the reinforcement. For design purposes the protection shall be disregarded, considered as carrying no load.

FIRE-RESISTIVE RATING OF FLOORS.

(a) A 4-hour floor shall consist of reinforced concrete or solid masonry slabs or arches, minimum 4" thickness, or 4" hollow masonry slabs or arches with 2" solid slab on top. All steel to have 4-hour protection.

(b) A 3-hour floor shall consist of reinforced concrete or solid masonry slabs or arches, minimum 2½" thickness, or 4" hollow masonry slabs or arches with 1½" solid slab on top. All steel, 3-hour protection.

(c) A 2-hour floor shall consist of reinforced concrete or solid masonry slabs or arches, minimum 2½" thickness or 3" hollow masonry slabs or arches with 1" solid slab on top. All steel to have 2-hour protection.

(d) A 1-hour floor shall consist of reinforced concrete or solid masonry slabs or arches, minimum 2½" thickness, or 3" hollow masonry slabs or arches with all joints thoroughly filled with mortar. All steel to have 1 hour protection. Wood joist with double wood floor above and one hour ceiling below the joist, rated one hour construction.

CLASSIFICATION REQUIREMENTS. Fire-resistive construction (often called "fireproof") is the highest type classified. Buildings of this type more than eight stories, or 85 feet, in height, shall have 4-hour protection for all columns and all primary beams and girders, and 3-hour protection of floors. For this type structure less than eight stories or 85 feet in height, columns and primary beams and girders shall have 3-hour protection, and 2-hour protection for floors. Masonry over window openings may be supported by a steel lintel, not fireproofed on under side, provided this lintel is supported at proper intervals from a fully fireproofed beam or girder. For openings not exceeding four feet in width, the lintel need not be so supported, but may be carried on masonry.

Adapted from Singleton, Manual of Structural Design, H. M. Ives & Sons.

WIRE AND SHEET METAL GAGES

IN DECIMALS OF AN INCH

Name of Gage	United States Standard Gage*		American Steel & Wire Co.,** and John A. Roebling Sons Co.	American or Brown & Sharpe Wire Gage	New Birmingham Standard Sheet & Hoop Gage	British Imperial or English Legal Standard Wire Gage	Birmingham or Stubs Iron Wire Gage	Name of Gage
Principal Use	Uncoated Steel Sheets and Light Plates		Steel Wire except Music Wire	Non-Ferrous Sheets and Wire	Iron and Steel Sheets and Hoops	Wire	Strips, Bands, Hoops and Wire	Principal Use
Gage No.	Weight Lb per Sq Ft	Approx. Thickness Inches	Thickness, Inches					Gage No
7/0's	20 00	.4902	.4900		.6666	.500		7/0's
6/0's	18.75	.4596	.4615	.5800	.625	.464		6/0's
5/0's	17.50	.4289	.4305	.5165	.5883	.432	.500	5/0's
4/0's	16.25	.3983	.3938	.4600	.5416	.400	.454	4/0's
3/0's	15 00	.3676	.3625	.4096	.500	.372	.425	3/0's
2/0's	13.75	.3370	.3310	.3648	.4452	.348	.380	2/0's
0	12.50	.3064	.3065	.3249	.3964	.324	.340	0
1	11.25	.2757	.2830	.2893	.3532	.300	.300	1
2	10 625	.2604	.2625	.2576	.3147	.276	.284	2
3	10 00	.2451	.2437	.2294	.2804	.252	.259	3
4	9.375	.2298	2253	.2043	.250	.232	.238	4
5	8.75	.2145	.2070	.1819	.2225	.212	.220	5
6	8 125	.1991	.1920	.1620	.1981	.192	.203	6
7	7 50	.1838	.1770	.1443	.1764	.176	.180	7
8	6 875	.1685	.1620	.1285	.1570	.160	.165	8
9	6 25	.1532	.1483	.1144	.1398	.144	.148	9
10	5.625	.1379	.1350	.1019	.1250	.128	.134	10
11	5.00	.1225	.1205	.0907	.1113	.116	.120	11
12	4.375	.1072	.1055	.0808	.0991	.104	.109	12
13	3 75	.0919	.0915	.0720	.0882	.092	.095	13
14	3.125	.0766	.0800	.0641	.0785	.080	.083	14
15	2.8125	.0689	.0720	.0571	.0699	.072	.072	15
16	2 50	.0613	.0625	.0508	.0625	.064	.065	16
17	2.25	.0551	.0540	.0453	.0556	.056	.058	17
18	2 00	.0490	.0475	.0403	.0495	.048	.049	18
19	1.75	.0429	.0410	.0359	.0440	.040	.042	19
20	1.50	.0368	.0348	.0320	.0392	.036	.035	20
21	1 375	.0337	.0318	.0285	.0349	.032	.032	21
22	1 25	.0306	.0286	.0253	.0313	.028	.028	22
23	1.125	.0276	.0258	.0226	.0278	.024	.025	23
24	1.00	.0245	.0230	.0201	.0248	.022	.022	24
25	.875	.0214	.0204	.0179	.0220	.020	.020	25
26	.75	.0184	.0181	.0159	.0196	.018	.018	26
27	.6875	.0169	.0173	.0142	.0175	.0164	.016	27
28	.625	.0153	.0162	.0126	.0156	.0148	.014	28
29	.5625	.0138	.0150	.0113	.0139	.0136	.013	29
30	.50	.0123	.0140	.0100	.0123	.0124	.012	30
31	.4375	.0107	.0132	.0089	.0110	.0116	.010	31
32	.4062	.0100	.0128	.0080	.0098	.0108	.009	32
33	.375	.0092	.0118	.0071	.0087	.0100	.008	33
34	.3438	.0084	.0104	.0063	.0077	.0092	.007	34
35	.3125	.0077	.0095	.0056	.0069	.0084	.006	35
36	.2812	.0069	.0090	.0050	.0061	0076	.004	36
37	2656	.0065	.0085	.0045	.0054	0068		37
38	.25	.0061	.0080	.0040	.0048	0060		38
39	.2344	.0057	.0075	.0035	.0043	0052		39
40	.2188	.0054	.0070	.0031	.0039	.0048		40

*U. S. Standard Gage is officially a weight gage (in ounces per sq. ft.) based on wrought iron at 480 lb. per cu. ft. The values tabulated above give the thickness of steel (at 489 6 lb. per cu. ft.) that will approximate the respective weights. The other gages are officially thickness gages.
Plates—Over 6" to 48" wide, 1/4" and thicker; over 48" wide, [illegible]/16" and thicker.
Sheets—24" to 48" wide, under 1/4" thick; over 48" wide, under 3/16" thick.
Strip—23 15/16" and narrower, under 1/4" thick.

** *Formerly Washburn & Moen.*

Adapted from American Institute of Steel Construction.

STRUCTURAL – CONVERSION FACTORS-1

TABLES OF CONVERSION FACTORS FOR ENGINEERS

Data are arranged alphabetically.

Unless designated otherwise, the English measures of capacity are those used in the United States, and the units of weight and mass are avoirdupois units.

The word gallon, used in any conversion factor, designates the U. S. gallon. To convert into the Imperial gallon, multiply the U. S. gallon by 0.83267. Likewise, the word ton designates a short ton, 2,000 pounds.

The figures 10^{-1}, 10^{-2}, 10^{-3}, etc. denote 0.1, 0.01, 0.001, etc. respectively.

The figures 10^{1}, 10^{2}, 10^{3}, etc. denote 10, 100, 1000, etc. respectively.

With respect to the properties of water, it freezes at 32°F., and is at its maximum density at 39.2°F. In the conversion factors given below using the properties of water, calculations are based on water at 39.2°F. in vacuo, weighing 62.427 pounds per cubic foot, or 8.345 pounds per U. S. gallon.

"Parts Per Million," designated as P.P.M., is always by weight and is simply a more convenient method of expressing concentration, either dissolved or undissolved material. Usually P.P.M. is used where percentage would be so small as to necessitate several ciphers after the decimal point, as one part per million is equal to 0.0001 per cent.

As used in the Sanitary field, P.P.M. represents the number of pounds of dry solids contained in one million pounds of water, including solids. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U. S. gallons of water. In the Metric system, one part per million may be expressed as one gram of dry solids to one million grams of water, or one milligram per liter.

In arriving at parts per million by means of pounds per million gallons or milligrams per liter, it may be mentioned that the density of the solution or suspension has been neglected and if this is appreciably different from unity, the results are slightly in error.

Multiply	*By*	*To Obtain*
Acres	43,560	Square feet
"	4047	Square meters
"	1.562×10^{-3}	Square miles
"	4840	Square yards
Acre-feet	43,560	Cubic feet
" "	325,851	Gallons
" "	1233.49	Cubic meters
Atmospheres	76.0	Cms. of mercury
"	29.92	Inches of mercury
"	33.90	Feet of water
"	10,333	Kgs./sq. meter
"	14.70	Lbs./sq. inch
"	1.058	Tons/sq. ft.
Barrels–oil	42	Gallons–oil
" –cement	376	Pounds–cement
Bags or sacks–cement	94	Pounds–cement
Board–feet	144 sq. in. x 1 in.	Cubic inches
British Thermal Units	0.2520	Kilogram–calories
" " "	777.5	Foot-lbs.
" " "	3.927×10^{-4}	Horse-power-hrs.
" " "	107.5	Kilogram-meters
" " "	2.928×10^{-4}	Kilowatt-hrs.
B.T.U./min	12.96	Foot-lbs./sec.
" / "	0.02356	Horse-power
" / "	0.01757	Kilowatts
" / "	17.57	Watts
Centares (Centiares)	1	Square meters
Centigrams	0.01	Grams
Centiliters	0.01	Liters
Centimeters	0.3937	Inches
"	0.01	Meters
"	10	Millimeters
Centimtrs. of mercury	0.01316	Atmospheres
" " "	0.4461	Feet of water
" " "	136.0	Kgs./sq. meter
" " "	27.85	Lbs./sq. ft.
" " "	0.1934	Lbs./sq. inch
Centimeters/second	1.969	Feet/min.
" / "	0.03281	Feet/sec.
Centimeters/second	0.036	Kilometers/hr.
" / "	0.6	Meters/min.
" / "	0.02237	Miles/hr.
" / "	3.728×10^{-4}	Miles/min.
Chain (Gunters)	66	Feet
Cms./sec./sec.	0.03281	Feet/sec./sec.
Cubic centimeters	3.531×10^{-5}	Cubic feet
" "	6.102×10^{-2}	Cubic inches
" "	10^{-6}	Cubic meters
" "	1.308×10^{-6}	Cubic yards
" "	2.642×10^{-4}	Gallons
" "	10^{-3}	Liters
" "	2.113×10^{-3}	Pints (liq.)
" "	1.057×10^{-3}	Quarts (liq.)
Cubic feet	2.832×10^{4}	Cubic cms.
" "	1728	Cubic inches
" "	0.02832	Cubic meters
" "	0.03704	Cubic yards
" "	7.48052	Gallons
" "	28.32	Liters
" "	59.84	Pints (liq.)
" "	29.92	Quarts (liq.)
Cubic feet/minute	472.0	Cubic cms./sec.
" " / "	0.1247	Gallons/sec.
" " / "	0.4720	Liters/sec.
" " / "	62.43	Pounds of water/min.
Cubic feet/second	0.646317	Million gals./day
" " / "	448.831	Gallons/min.
" " / "	13.8 / sq. mi. drainage area	Inches / year
Cubic inches	16.39	Cubic centimeters
" "	5.787×10^{-4}	Cubic feet
" "	1.639×10^{-5}	Cubic meters
" "	2.143×10^{-5}	Cubic yards
" "	4.329×10^{-3}	Gallons
" "	1.639×10^{-2}	Liters
" "	0.03463	Pints (liq.)
" "	0.01732	Quarts (liq.)
Cubic meters	10^{6}	Cubic centimeters
" "	35.31	Cubic feet
" "	61,023	Cubic inches
" "	1.308	Cubic yards
" "	264.2	Gallons
Cubic meters	10^{3}	Liters
" "	2113	Pints (liq.)
" "	1057	Quarts (liq.)
Cubic yards	7.646×10^{5}	Cubic centimeters
" "	27	Cubic feet
" "	46,656	Cubic inches
" "	0.7646	Cubic meters
" "	202.0	Gallons
" "	764.6	Liters
" "	1616	Pints (liq.)
" "	807.9	Quarts (liq.)
Cubic yards/min	0.45	Cubic feet/sec.
" " / "	3.367	Gallons/sec.
" " / "	12.74	Liters/sec.
Decigrams	0.1	Grams
Deciliters	0.1	Liters
Decimeters	0.1	Meters
Degrees (angle)	60	Minutes
" "	0.01745	Radians
" "	3600	Seconds
Degrees/sec	0.01745	Radians/sec.
" / "	0.1667	Revolutions/min.
" / "	0.002778	Revolutions/sec.
Dekagrams	10	Grams
Dekaliters	10	Liters
Dekameters	10	Meters
Drams	27.34375	Grains
"	0.0625	Ounces
"	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
"	12	Inches
"	0.3048	Meters
"	1/3	Yards

Adapted from Tables of Conversion Factors for Engineers by The Dorr Co.

STRUCTURAL - CONVERSION FACTORS-2

Multiply	By	To Obtain
Feet of water	0.02950	Atmospheres
" " "	0.8826	Inches of mercury
" " "	304.8	Kgs./sq.meter
" " "	62.43	Lbs./sq.ft.
" " "	0.4335	Lbs./sq.inch
Feet/min.	0.5080	Centimeters/sec.
" / "	0.01667	Feet/sec.
" / "	0.01829	Kilometers/hr.
" / "	0.3048	Meters/min.
" / "	0.01136	Miles/hr.
Feet/sec.	30.48	Centimeters/sec.
" / "	1.097	Kilometers/hr.
" / "	0.5921	Knots
" / "	18.29	Meters/min.
" / "	0.6818	Miles/hr.
" / "	0.01136	Miles/min.
Feet/sec./sec	30.48	Cms./sec./sec.
" / " / "	0.3048	Meters/sec./sec.
Foot-pounds	1.286×10^{-3}	British Thermal Units
" "	5.050×10^{-7}	Horse-power-hrs.
" "	3.241×10^{-4}	Kilogram-calories
" "	0.1383	Kilogram-meters
" "	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	1.286×10^{-3}	B. T. Units/min.
" " / "	0.01667	Foot-pounds/sec.
" " / "	3.030×10^{-5}	Horse-power
" " / "	3.241×10^{-4}	Kg.-calories/min.
" " / "	2.260×10^{-5}	Kilowatts
Foot-pounds/sec.	7.717×10^{-2}	B. T. Units/min.
" " / "	1.818×10^{-3}	Horse-power
" " / "	1.945×10^{-2}	Kg.-calories/min.
" " / "	1.356×10^{-3}	Kilowatts
Gallons	3785	Cubic centimeters
"	0.1337	Cubic feet
"	231	Cubic inches
"	3.785×10^{-3}	Cubic meters
"	4.951×10^{-3}	Cubic yards
"	3.785	Liters
"	8	Pints (liq.)
"	4	Quarts (liq.)
Kgs./sq. meter	9.678×10^{-5}	Atmospheres
" / " "	3.281×10^{-3}	Feet of water
" / " "	2.896×10^{-3}	Inches of mercury
" / " "	0.2048	Lbs./sq. foot
" / " "	1.422×10^{-3}	Lbs./sq. inch
Kgs./sq. millimeter	10^{6}	Kgs./sq. meter
Kiloliters	10^{3}	Liters
Kilometers	10^{5}	Centimeters
"	3281	Feet
"	10^{3}	Meters
"	0.6214	Miles
"	1094	Yards
Kilometers/hr.	27.78	Centimeters/sec.
" / "	54.68	Feet/min.
" / "	0.9113	Feet/sec.
" / "	0.5396	Knots
" / "	16.67	Meters/min.
" / "	0.6214	Miles/hr.
Kms./hr./sec.	27.78	Cms./sec./sec.
" / " / "	0.9113	Ft./sec./sec.
" / " / "	0.2778	Meters/sec./sec.
Kilowatts	56.92	B.T. Units/min.
"	4.425×10^{4}	Foot-lbs./min.
"	737.6	Foot-lbs./sec.
"	1.341	Horse-power
"	14.34	Kg.-calories/min.
"	10^{3}	Watts
Kilowatt-hours	3415	British Thermal Units
" "	2.655×10^{6}	Foot-lbs.
" "	1.341	Horse-power-hrs.
" "	860.5	Kilogram-calories
" "	3.671×10^{5}	Kilogram-meters
Link (Gunters)	66	Feet
Liters	10^{3}	Cubic centimeters
"	0.03531	Cubic feet
"	61.02	Cubic inches
"	10^{-3}	Cubic meters
"	1.308×10^{-3}	Cubic yards
"	0.2642	Gallons
"	2.113	Pints (liq.)
"	1.057	Quarts (liq.)

Multiply	By	To Obtain
Gallons, Imperial.	1.20095	U.S. gallons
" U.S.	0.83267	Imperial gallons
Gallons water	8.3453	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
" / "	0.06308	Liters/sec.
" / "	8.0208	Cu. ft./hr.
" / "	$\dfrac{8.0208}{\text{Area (sq. ft.)}}$	Overflow rate (ft./hr.)
Gallons water/min	6.0086	Tons water/24 hrs.
Grains (troy)	L	Grains (avoir.)
" "	0.06480	Grams
" "	0.04167	Pennyweights (troy)
" "	2.0833×10^{-3}	Ounces (troy)
Grains/U.S. gal.	17.118	Parts/million
" /U.S. gal.	142.86	Lbs./million gal.
" /Imp. gal.	14.286	Parts/million
Grams	980.7	Dynes
"	15.43	Grains
"	10^{-3}	Kilograms
"	10^{3}	Milligrams
"	0.03527	Ounces
"	0.03215	Ounces (troy)
"	2.205×10^{-3}	Pounds
Grams/cm.	5.600×10^{-3}	Pounds/inch
Grams/cu. cm.	62.43	Pounds/cubic foot
" / " "	0.03613	Pounds/cubic inch
Grams/liter	58.417	Grains/gal.
" / "	8.345	Pounds/1000 gals.
" / "	0.062427	Pounds/cubic foot
" / "	1000	Parts/million
Hectares	2.471	Acres
"	1.076×10^{5}	Square feet
Hectograms	100	Grams
Hectoliters	100	Liters
Hectometers	100	Meters
Hectowatts	100	Watts
Liters/min.	5.886×10^{-4}	Cubic ft.-sec.
" / "	4.403×10^{-3}	Gals.-/sec.
$\dfrac{\text{Lumber Width (in.) x Thickness (in.)}}{12}$	Length (ft)	Board Feet
Meters	100	Centimeters
"	3.281	Feet
"	39 37	Inches
"	10^{-3}	Kilometers
"	10^{3}	Millimeters
"	1.094	Yards
Meters/min.	1.667	Centimeters/sec.
" / "	3.281	Feet/min.
" / "	0.05468	Feet/sec.
" / "	0.06	Kilometers/hr.
" / "	0.03728	Miles/hr.
Meters/sec.	196.8	Feet/min.
" / "	3.281	Feet/sec.
" / "	3.6	Kilometers/hr.
" / "	0.06	Kilometers/min.
" / "	2.237	Miles/hr.
" / "	0.03728	Miles/min.
Microns	10^{-6}	Meters
Miles	1.609×10^{5}	Centimeters
"	5280	Feet
"	1.609	Kilometers
"	1760	Yards
Miles/hr.	44.70	Centimeters/sec.
" / "	88	Feet/min.
" / "	1.467	Feet/sec.
" / "	1.609	Kilometers/hr.
" / "	0.8684	Knots
" / "	26.82	Meters/min.
Miles/min.	2682	Centimeters/sec.
" / "	88	Feet/sec.
" / "	1.609	Kilometers/min.
" / "	60	Miles/hr.
Milliers	10^{3}	Kilograms
Milligrams	10^{-3}	Grams
Milliliters	10^{-3}	Liters

Multiply	By	To Obtain
Horse-power	42 44	B.T. Units/min.
" "	33,000	Foot-lbs./min.
" "	550	Foot-lbs./sec.
" "	1.014	Horse-power (metric)
" "	10.70	Kg.-calories/min.
" "	0.7457	Kilowatts
" "	745.7	Watts
Horse-power (boiler)	33,479	B.T.U./hr.
" " "	9.803	Kilowatts
Horse-power-hours	2547	British Thermal Units
" " "	1.98×10^{6}	Foot-lbs.
" " "	641.7	Kilogram-calories
" " "	2.737×10^{5}	Kilogram-meters
" " "	0.7457	Kilowatt-hours
Inches	2.540	Centimeters
Inches of mercury	0.03342	Atmospheres
" " "	1.133	Feet of water
" " "	345.3	Kgs./sq. meter
" " "	70.73	Lbs./sq. ft.
" " "	0.4912	Lbs./sq. inch
Inches of water	0.002458	Atmospheres
" " "	0 07355	Inches of mercury
" " "	25.40	Kgs./sq. meter
" " "	0.5781	Ounces/sq. inch
" " "	5.202	Lbs./sq. foot
" " "	0.03613	Lbs./sq. inch
" " " / year	$\dfrac{\text{sq. mi.}}{13.8}$	Cu. ft. / sec.
Kilograms	980,665	Dynes
"	2.205	Lbs.
"	1.102×10^{-3}	Tons (short)
"	10^{3}	Grams
Kilograms-calories	3.968	British Thermal Units
" "	3086	Foot-pounds
" "	1.558×10^{-3}	Horse-power-hours
" "	1.162×10^{-3}	Kilowatt-hours
Kilogram-calories/min.	51.43	Foot-pounds/sec.
" " / "	0.09351	Horse-power
" " / "	0.06972	Kilowatts
Kgs./meter	0.6720	Lbs./foot
Millimeters	0.1	Centimeters
"	0.03937	Inches
Milligrams/liter	1	Parts/million
Million gals./day	1.54723	Cubic ft./sec.
Miner's inches	1.5	Cubic ft./min.
Minutes (angle)	2.909×10^{-4}	Radians
Ounces	16	Drams
"	437.5	Grains
"	0.0625	Pounds
"	28.349527	Grams
"	0.9115	Ounces (troy)
"	2.790×10^{-5}	Tons (long)
"	2.835×10^{-5}	Tons (metric)
Ounces, troy	480	Grains
" "	20	Pennyweights (troy)
" "	0.08333	Pounds (troy)
" "	31.103481	Grams
" "	1.09714	Ounces, avoir.
Ounces (fluid)	1.805	Cubic inches
" "	0.02957	Liters
Ounces/sq. inch	0.0625	Lbs./sq. inch
Overflow rate (ft./hr.)	0.12468 x area (sq. ft.)	Gals./min.
$\dfrac{1}{\text{Overflow rate (ft./hr.)}}$	8.0208	Sq. ft./gal./min.
Parts/million	0.0584	Grains/U.S. gal.
" / "	0.07016	Grains/Imp. gal.
" / "	8.345	Lbs./million gal.
Pennyweights (troy)	24	Grains
" "	1.55517	Grams
" "	0.05	Ounces (troy)
" "	4.1667×10^{-3}	Pounds (troy)
Pounds	16	Ounces
"	256	Drams
"	7000	Grains
"	0.0005	Tons (short)
"	453.5924	Grams
"	1.21528	Pounds (troy)
"	14.5833	Ounces (troy)

Adapted from Tables of Conversion Factors for Engineers by The Dorr Co.

STRUCTURAL - CONVERSION FACTORS-3

Multiply	*By*	*To Obtain*
Pounds (troy)	5760	Grains
" "	240	Pennyweights (troy)
" "	12	Ounces (troy)
" "	373.24177	Grams
" "	0.822857	Pounds (avoir.)
" "	13.1657	Ounces (avoir.)
" "	3.6735×10^{-4}	Tons (long)
" "	4.1143×10^{-4}	Tons (short)
" "	3.7324×10^{-4}	Tons (metric)
Pounds of water	0.01602	Cubic feet
" " "	27.68	Cubic inches
" " "	0.1198	Gallons
Pounds of water/min.	2.670×10^{-4}	Cubic ft./sec.
Pounds/cubic foot	0.01602	Grams/cubic cm.
" / " "	16.02	Kgs./cubic meter
" / " "	5.787×10^{-4}	Lbs./cubic inch
Pounds/cubic inch	27.68	Grams/cubic cm.
" / " "	2.768×10^{4}	Kgs./cubic meter
" / " "	1728	Lbs./cubic foot
Pounds/foot	1.488	Kgs./meter
Pounds/inch	178.6	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
" / " "	4.883	Kgs./sq. meter
" / " "	6.945×10^{-3}	Pounds/sq. inch
Pounds/sq. inch	0.06804	Atmospheres
" / " "	2.307	Feet of water
" / " "	2.036	Inches of mercury
" / " "	703.1	Kgs./sq. meter
Quadrants (angle)	90	Degrees
" "	5400	Minutes
" "	1.571	Radians
Quarts (dry)	67.20	Cubic inches
Quarts (liq.)	57.75	Cubic inches
Quintal, Argentine	101.28	Pounds
" Brazil	129.54	Pounds
" Castile, Peru	101.43	Pounds
" Chile	101.41	Pounds
" Mexico	101.47	Pounds
" Metric	220.46	Pounds
Square inches	6.452	Square centimeters
" "	6.944×10^{-3}	Square feet
" "	645.2	Square millimeters
Square kilometers	247.1	Acres
" "	10.76×10^{6}	Square feet
" "	10^{6}	Square meters
" "	0.3861	Square miles
" "	1.196×10^{6}	Square yards
Square meters	2.471×10^{-4}	Acres
" "	10.76	Square feet
" "	3.861×10^{-7}	Square miles
" "	1.196	Square yards
Square miles	640	Acres
" "	27.88×10^{6}	Square feet
" "	2.590	Square kilometers
" "	3.098×10^{6}	Square yards
Square millimeters	0.01	Square centimeters
" "	1.550×10^{-3}	Square inches
Square yards	2.066×10^{-4}	Acres
" "	9	Square feet
" "	0.8361	Square meters
" "	3.228×10^{-7}	Square miles
Temp. (°C.) + 273	1	Abs. temp. (°C.)
" " + 17.78	1.8	Temp. (°F.)
" (°F.) + 460	1	Abs. temp. (°F.)
" " — 32	5/9	Temp. (°C.)
Tons (long)	1016	Kilograms
" "	2240	Pounds
" "	1.12000	Tons (short)
Tons (metric)	10^{3}	Kilograms
" "	2205	Pounds
Tons (short)	2000	Pounds
" "	32000	Ounces
" "	907.18486	Kilograms

Multiply	*By*	*To Obtain*
Quires	25	Sheets
Radians	57.30	Degrees
"	3438	Minutes
"	0.637	Quadrants
Radians/sec.	57.30	Degrees/sec.
" / "	0.1592	Revolutions/sec.
" / "	9.549	Revolutions/min.
Radians/sec./sec.	573.0	Revolutions/min/min
" / " / "	0.1592	Revolutions/sec./sec.
Reams	500	Sheets
Revolutions	360	Degrees
"	4	Quadrants
"	6.283	Radians
Revolutions/min.	6	Degrees/sec.
" / "	0.1047	Radians/sec.
" / "	0.01667	Revolutions/sec.
Revolutions/min./min.	1.745×10^{-3}	Rads./sec./sec.
" / " / "	2.778×10^{-4}	Revs./sec./sec.
Revolutions/sec.	360	Degrees/sec.
" / "	6.283	Radians/sec.
" / "	60	Revolutions/min.
Revolutions/sec./sec.	6.283	Radians/sec./sec.
" / " / "	3600	Revolutions/min/min.
Rods	16.5	Feet
Seconds (angle)	4.848×10^{-6}	Radians
Square centimeters	1.076×10^{-3}	Square feet
" "	0.1550	Square inches
" "	10^{-4}	Square meters
" "	100	Square millimeters
Square Chains (Gunters)	16	Square rods
Square feet	2.296×10^{-5}	Acres
" "	929.0	Square centimeters
" "	144	Square inches
" "	0.09290	Square meters
" "	3.587×10^{-8}	Square miles
" "	1/9	Square yards
$\dfrac{1}{\text{Sq. ft./gal./min.}}$	8.0208	Overflow rate (ft./hr.)
Tons (short)	2430.56	Pounds (troy)
" "	0.89287	Tons (long)
" "	29166.66	Ounces (troy)
" "	0.90718	Tons (metric)
$\dfrac{1}{\text{Tons dry solids/24 hrs.}}$	Area (sq. ft.)	Sq.ft./ton/24 hrs.
Tons of water/24 hrs.	83.333	Pounds water/hour
" " " / "	0.16643	Gallons/min.
" " " / "	1.3349	Cu. ft./hr.
Watts	0.05692	B. T. Units/min.
"	44.26	Foot-pounds/min.
"	0.7376	Foot-pounds/sec.
"	1.341×10^{-3}	Horse-power
"	0.01434	Kg.-calories/min.
"	10^{-3}	Kilowatts
Watt-hours	3.415	British Thermal Units
"	2655	Foot-pounds
"	1.341×10^{-3}	Horse-power-hours
"	0.8605	Kilogram-calories
"	367.1	Kilogram-meters
"	10^{-3}	Kilowatt-hours
Yards	91.44	Centimeters
"	3	Feet
"	36	Inches
"	0.9144	Meters

Adapted from Tables of Conversion Factors for Engineers by Dorr Co.

STRUCTURAL - GENERAL NOTES - 1

CONCRETE

DESIGN DRAWINGS:

Concrete shall develop a strength of ____ lb. per. sq. in. at 28 days.

In two-way slabs place short span bars in bottom layer.

Concrete beams to have 8 in. bearing on walls unless otherwise noted.

Metal tile joists to have not less than 6 in. bearing on walls.

Clay tile joists to have 6 in. bearing on walls.

Solid slabs to have 4 in. bearing on walls.

Brick pilasters in tile back-up walls required for bearing to be bonded into adjoining masonry.

Steel beams carrying chimneys or other masonry to be fireproofed with stone concrete.

Fireproofing thickness shall be 1 in. for slabs, 2 in. for steel beams and girders. Interior steel columns to have 2 in. fireproofing.

Provide adequate ties for all steel bars and stirrups in slabs and beams. All reinforcing steel in slabs and beams to be held at correct distance from forms by adequate concrete blocks, steel chairs, or ties.

(See specifications for instructions to detailers.)

WORKING DRAWINGS: (Include in specification.)

Concrete shall develop a strength of ______ lb. per. sq. in. at 28 days.*

Follow A.C.I. rules as to stirrups, column ties, and anchorages. Design is based on f'_c. Details of web reinforcement and anchorages must be carried out accordingly, unless otherwise shown. (See pages 1-01 and 1-29.)

Where concrete beams frame into steel, provide 2-3/4 in. round anchor bolts with double nuts through web or hooks over flanges except as otherwise noted.

Provide ______ header bars in slab in front of all openings and chases in bearing walls unless otherwise shown.

Metal tile slabs to be anchored to walls with 5/8"in. round anchors 4 ft. long with 6 in. hook at wall end, placed in alternate joists.

Metal tile joists to be 25 in. o.c. except as shown. Steel shown in slab schedules is per joist.

Topping of metal tile joist slabs to be 2 in. thicker than typical each side of concrete beams parallel to joists.

Where joists run parallel to wall provide 1/2 in. round anchors 3 ft. 6 in. long with 6 in. hooks at right angles to joists 4 ft. o.c. in 2 in. topping.

Working drawings to show tee flanges on beams of sufficient width and thickness to develop full strength of steel.

Provide 1/4 in. round stirrups 12 in. o.c. for beams and joists with top steel for sections where no stirrups are called for.

Provide 2-3/8 in. round tie rods in top of all concrete beams to fasten stirrups where no top steel occurs.

Provide 1/4 in. round rods 12 in. o.c. at right angles to joists in top of all metal tile and joist slabs.

Provide longitudinal or temperature reinforcement in solid slabs in accordance with A.C.I. code. (See page 1-29.)

Provide 100 per cent continuity over supports for all continuous slabs, beams, and joists unless otherwise noted.

In all solid slabs bend up alternate bars and extend into adjacent spans where continuous unless otherwise noted on plans.

Provide 3/8 in. round rods 12 in. o.c. extending into slab 2 ft. each side of beam where solid slabs are parallel to beams. Where slab occurs on one side only provide 6 in. hook.

All negative moment rods to extend to quarter points of spans.

* This note to be placed on working drawings.

STRUCTURAL - GENERAL NOTES - 2

At ends of noncontinuous beams provide anchor bars in top of beam. Anchors to be equivalent to 1/3 of main reinforcement but not less than 2-3/4 in. round by 4 ft. long unless noted.

Steel bars in noncontinuous beams to be provided with hooks where required by A.C.I. code. (See page 1-25.)

At supports of continuous beams extend bottom bars beyond center of support as shown on detail and as required for anchorage in accordance with A.C.I. code. Where 3 bars occur lap 2 bars from each side.

STEEL

DESIGN DRAWINGS:

All lintels shall have 6 in. minimum bearing each side unless otherwise noted.

Steel joists to have not less than 6 in. bearing on walls.

Where steel joists span more than 14 ft. provide safety headers of approved type.

All rivets to be____diameter unless otherwise noted. (Include on shop drawings.)

Provide standard bearing plates and government anchors for all steel beams resting on masonry except as otherwise shown.

Double steel beams and girders to be provided with pipe separators.

Provide soffit or mesh reinforcement for all steel beams and other members which are fireproofed with stone concrete.

Fireproofing thicknesses shall be as follows: Beams ________, columns ________.

WOOD

CONSTRUCTION DRAWINGS:

All wood shall be (give species and stress grade).

Provide 1-1/4 in. by 2 in. cross bridging not over 6 ft. o.c. for all wood joists.

Where wood joists frame into or rest on top of steel beams, provide 1-1/2 by 3/16 in. steel strap anchors spiked to wood joists and hooked over flange of beam at every third joist on each side of beam.

Where wood joists rest on masonry provide metal anchors at maximum intervals of 4 ft. o.c. having a minimum cross section 1/4 by 1-1/4 in. by minimum length of 16 in. securely fastened to joist and built into masonry with split or upset ends. Where joists are parallel to walls provide similar anchors at maximum spacing of 6 ft., engaging 3 joists.

Bolts and ring connectors shall be retightened periodically during process of seasoning.

Provide standard beam hangers for the beams framed into girders except as shown.

FOUNDATIONS

DESIGN DRAWINGS:

Foundations designed for_____tons per sq. ft. (check soil in field).

All concrete shall develop a strength of_____at 28 days, or as specified.

No backfilling against foundation walls to be done until after superstructure is in place.

Where reinforced mat slabs are erected and ground water pressure is likely to occur, relief holes should be left to relieve water pressure until approved by Engineer.

WORKING DRAWINGS: (Include in specification.)

Stone concrete shall develop a strength of_____lb. per sq. in. at 28 days.*

Wall footings to be stepped where elevation changes 1 vertical to 2 horizontal.

All bars in footings to be hooked. Size of hook to be in accordance with A.C.I. requirements. (See page 1-39.)

Provide 6-1/2 in. round rods continuous in top of all exterior concrete walls, except as otherwise shown. Lap 45 diameters and bend around corners.

Provide 2-1/2 in. round rods continuous in top of all interior concrete walls.

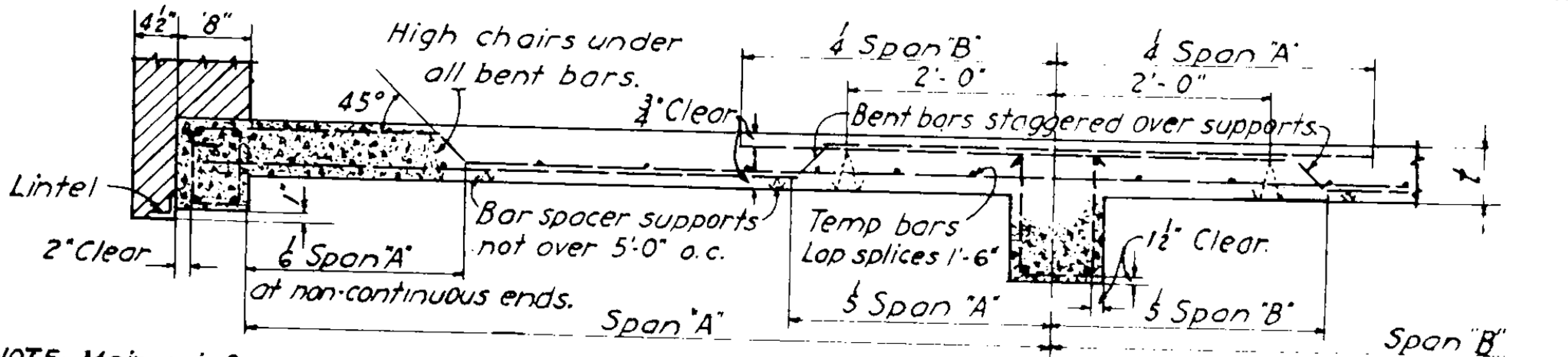
All wall pier footings shall be 12 in. thick and project 6 in. beyond all faces of walls, piers, and stacks, except as noted.

Provide 2-3/4 in. round rods, all sides, for all openings in concrete walls unless otherwise noted.

Provide pockets in walls for all concrete beams and slabs at first floor.

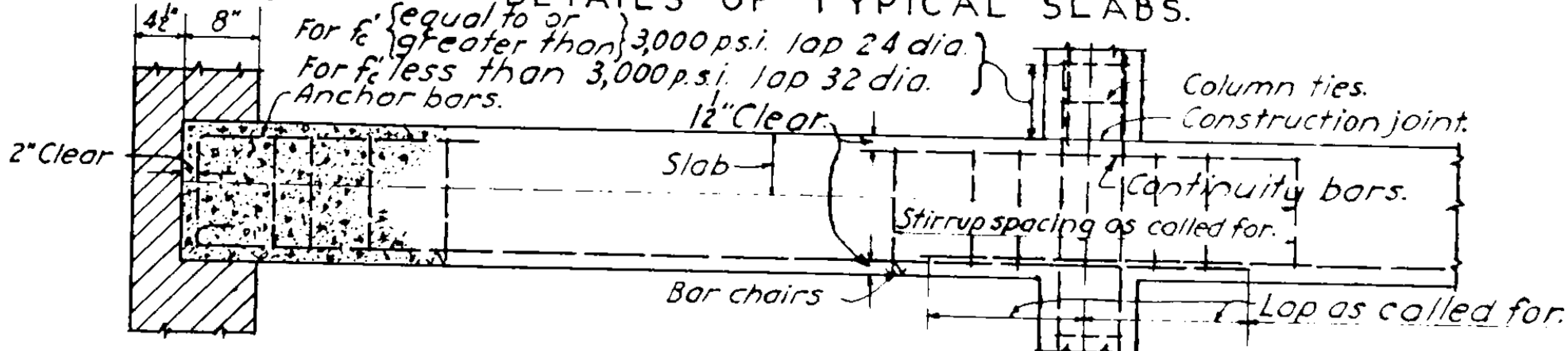
*This note to be placed on working drawings.

STRUCTURAL-CONCRETE DETAILS & ANCHORAGE*



NOTE: Main reinforcement: alternate bars to be bent up over support and staggered with bars from adjacent span.
At non-continuous ends of slabs, bent bars shall extend 3'-0" beyond ℄ of support.
Temperature bars shall project 4" into walls and beams at end conditions.
Temperature reinforcement-floors 3/8"φ-18" o.c.; roofs 3/8"φ-12" o.c.-for 4" slabs only.
Provide 3/8"φ x 6'-0"-12" o.c. in top of slabs over all supports where main reinforcement runs parallel to supports on both sides; and 3/8"φ x 3'-0"-12" o.c. in top of slabs over supports which are adjacent to openings where slabs frame parallel to supports.

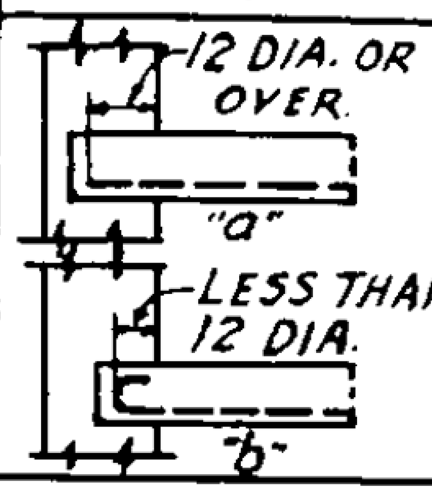
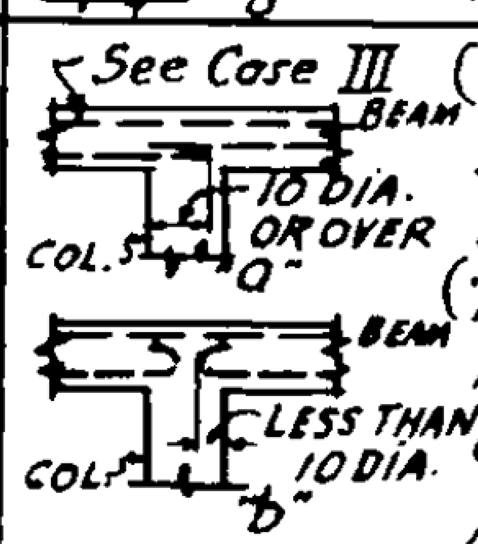
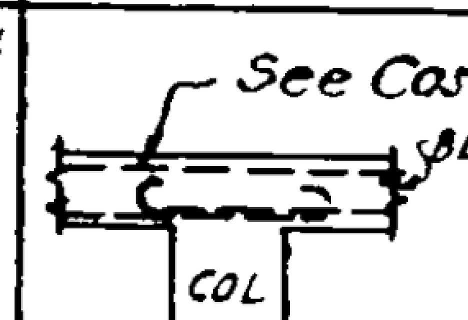
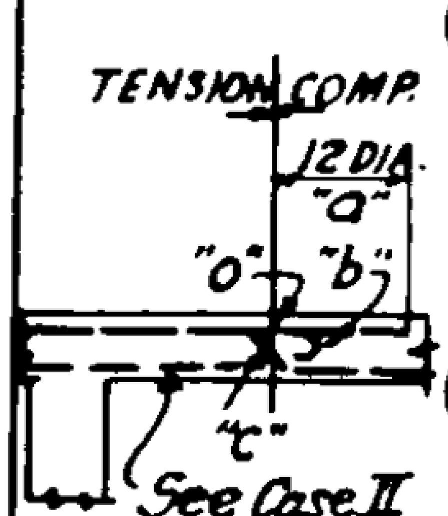
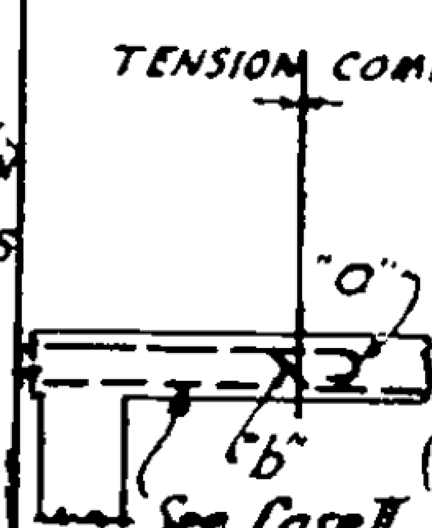
DETAILS OF TYPICAL SLABS.



DETAILS OF TYPICAL COLUMNS AND BEAMS.

FIG. A - CONCRETE DETAILS.

TABLE B - ANCHORAGE REQUIREMENTS.

	ORDINARY ANCHORAGE.	SPECIAL ANCHORAGE.
CASE I. NON-CONTINUOUS ENDS OF BEAMS.	 ("a"). ½ of positive reinforcement shall extend 12 or more bar diameters into support, or ("b"). If bars extend less than 12 diameters into support - provide standard hooks.	No special anchorage can be developed in the ends of unrestrained beams.
CASE II. POSITIVE REINFORCEMENT IN CONTINUOUS CONSTRUCTION.	 ("a"). ¼ of positive reinforcement shall extend 10 or more bar diameters into supports, or ("b"). If ¼ of positive reinforcement extends less than 10 diameters into support - provide standard hooks.	 All positive reinforcement shall be terminated with a standard hook in a compression region.
CASE III NEGATIVE REINFORCEMENT IN CONTINUOUS CONSTRUCTION.	 "O" = Point where bars are no longer needed to resist stress. ("a"). Extend no longer needed bars at least 12 bar diameters beyond point "O", or ("b"). Provide standard hooks beyond point "O" or ("c"). Bend the not needed bars across the web at an angle, not less than 15°, into region of compression and either make continuous with positive reinforcement or terminate with a standard hook.	 ("a"). All negative bars shall be terminated with a standard hook in compression region, or ("b") Bend the not needed bars across the web at an angle, not less than 15°, into region of compression and make continuous with positive reinforcement.

*In accordance with A.C.I. code - 1941.

STRUCTURAL - CONCRETE

APPROX. DATA ON CONCRETE MIXES

TABLE A. WATER-CEMENT RATIO (W/C) FOR VARIOUS STRENGTHS*

Water Content: Gallons per Sack of Cement	Water Content: Cu. Ft. per Sack	W/C Ratio by Absolute Volume	W/C Ratio by Weight	Strength of Concrete at 28 Days: Compressive	Strength of Concrete at 28 Days: Flexural
5 Max.	0.668	1.38	0.444	5000 p.s.i.	750 p.s.i.
6 Max.	0.802	1.66	0.533	4000 p.s.i.	600 p.s.i.
7 Max.	0.936	1.93	0.621	3200 p.s.i.	500 p.s.i.
8 Max.	1.069	2.21	0.710	2500 p.s.i.	450 p.s.i.

Note: W/C ratio should be determined by trial mixes when practicable.
To allow for field conditions the values shown in table should be reduced by about 20%.

* Joint Committee and P.R.A.

TABLE B. RECOMMENDED CONSISTENCY OR SLUMP OF CONCRETE**

Type of Structure	Slump in Inches Max.	Slump in Inches Min.
Reinforced foundation walls and footings	5	2
Plain footings and sub-structure walls	4	1
Slabs, beams, columns and reinforced walls	6	3
Pavement and mass concrete	3	1

** P.C.A.

TABLE C. EXPOSED CONCRETE - MAX. WATER CONTENT IN GALS. PER SACK***

Type or Location of Concrete	Severe and Moderate Climate	Mild Climate
At waterline (intermittent saturation)		
Sea water	5-1/2	5-1/2
Fresh water	6	6
Not at waterline but frequent wetting		
Sea water	6	6-1/2
Fresh water	6-1/2	7
Ordinary exposed structures	6-1/2	7
Completely submerged		
Sea water	6-1/2	6-1/2
Fresh water	7	7
Concrete deposited through water	5-1/2	5-1/2
Pavement slabs on ground		
Wearing slabs	5-1/2	6
Base slabs	6-1/2	7

Sand-Aggregate Ratio: or percentage by weight or volume of sand to total aggregate in mix should be from 33% to 45%, with extreme limits of 28% and 49%. Most economical mix will be that with lowest sand-aggregate ratio producing desired plasticity, workability and consistency.

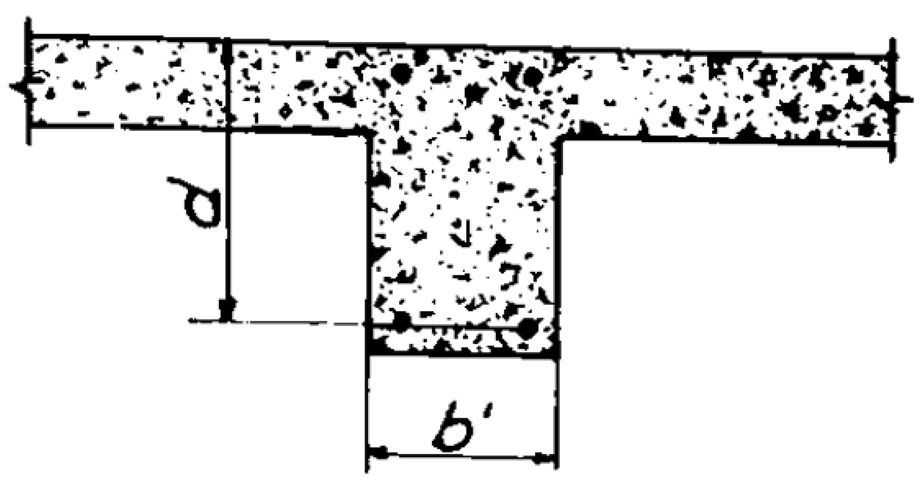
*** Joint Committee.

TABLE D. RECOMMENDED PER CENT OF SAND TO TOTAL AGGREGATE

Crushed Stone-Max. 1½" size	38 to 42	Gravel - Max. 1½" size	36 to 40
Crushed Stone-Max. ¾" size	43 to 49	Gravel - Max. ¾" size	39 to 44

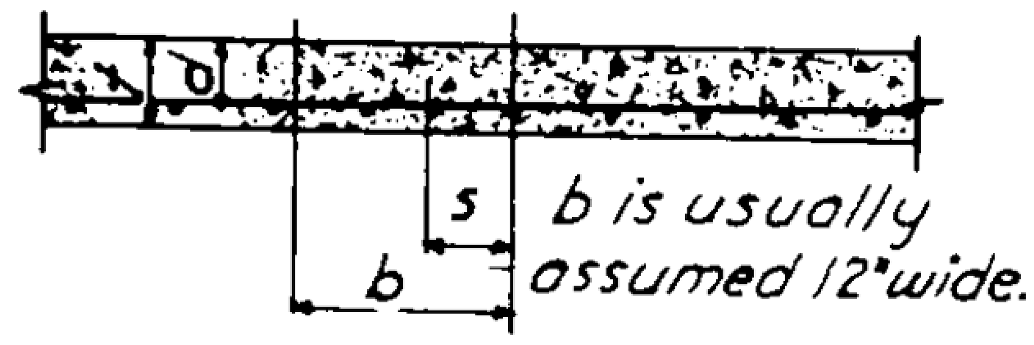
STRUCTURAL - CONCRETE

MISCELLANEOUS REQUIREMENTS OF A.C.I. CODE · 1941



Minimum Positive Reinforcement) .005db'.
Minimum Neg. Reinforcement) .005db' when outer end of members are built integral with supports.

BEAMS & GIRDERS.



Main Reinforcement:
Minimum area = .0025 db.
Maximum spacing of bars (s) = 3t

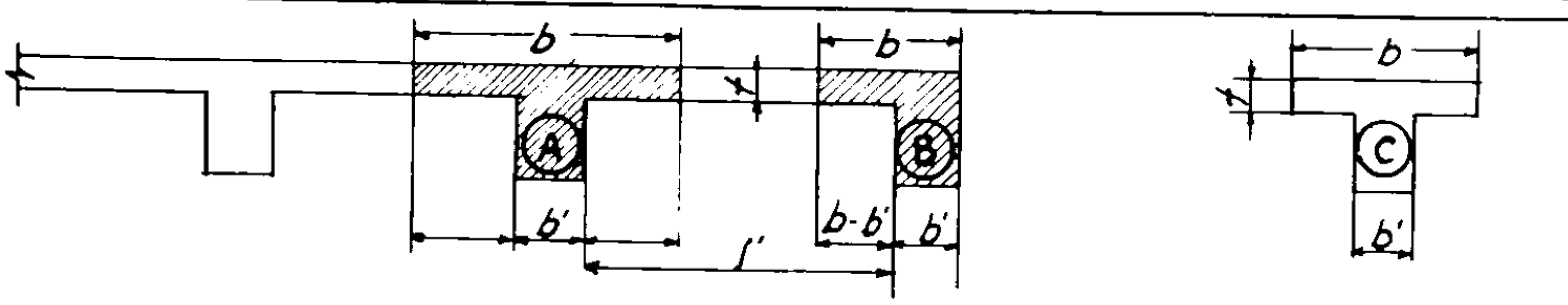
Temperature & Shrinkage Reinf.:
Minimum area = .002 db for floors.
" " = .0025 db for roofs.
Maximum spacing (S) = 5t, but not over 18".

ONE-WAY SLAB - UNIFORM THICKNESS.

Minimum Area: {Hor. Reinf. / Vert. Reinf.
Deformed Bars = .0025 x Cross sectional area of wall.
Wire Mesh = .0018 x Cross sectional area of wall.
Minimum Size of Reinf.
Deformed Bars: $\frac{3}{8}$"φ - 18" o.c.
Wire Mesh: #10 gage W & M.
Around openings - 2-$\frac{5}{8}$"φ (extend 24" beyond each corner).
Walls over 10" thick to have two layers of reinf. - $\frac{1}{2}$ to $\frac{2}{3}$ of total reinf. in exterior face, balance in interior face.

WALLS.

FIG. A - MINIMUM REINFORCEMENT.

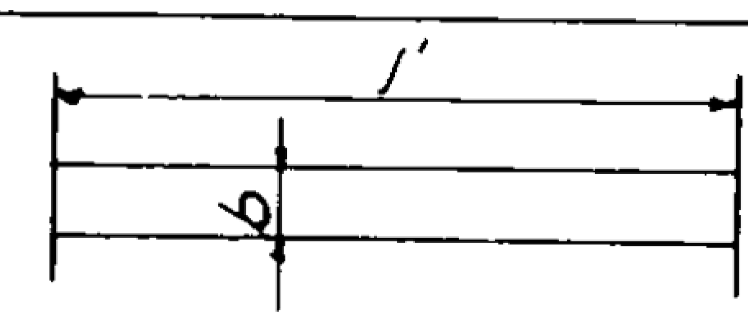


A - Symmetrical "T" Beam.
b ≤ $\frac{1}{4}$ Span length of beam.
$\frac{b-b'}{2} \leq 8t$ *or* $\frac{1}{2} l'$

B - One-Sided "T" Beam.
b - b' ≤ $\frac{1}{12}$ Span length of beam.
b - b' ≤ 6t or $\frac{1}{2} l'$

C - Isolated "T" Beam.
$t \geq \frac{1}{2} b'$
$b \leq 4b'$

FIG. B - "T" BEAMS.



PLAN

$l' \leq 32b$
l' = clear span.
b = least width of compression flange.

FIG. C - LATERAL SUPPORT OF BEAMS.

"K" - STIFFNESS FACTORS FOR ANALYSIS OF CONTINUOUS FRAMES.

FOR COLUMNS: $K = \frac{EI}{h}$; **FOR SLABS, BEAMS AND GIRDERS:** $K = \frac{EI}{l}$.

Where: E = Modulus of Elasticity; I = Moment of Inertia; h = Unsupported length of column; l = Length of span.

I for a rectangular section $= \frac{bd^3}{12}$ in.^{4}

I for a square section $= \frac{d^4}{12}$ in.^{4}

I for a circular section $= \frac{\pi r^4}{4}$ in.^{4}

For I of a "T" section see below.

EXAMPLE: I of a "T" section.
Given: b = 60"; b' = 12" and d = 24"
Required: To find moment of inertia.
Solution: $\frac{b}{b'} = \frac{60}{12} = 5$. *Enter Chart at* $\frac{b}{b'} = 5$, *go vertically to the curve - read C = 1.9*

$$I = 1.9 \times \frac{12 \times 24^3}{12} = 26{,}265 \text{ in.}^4$$

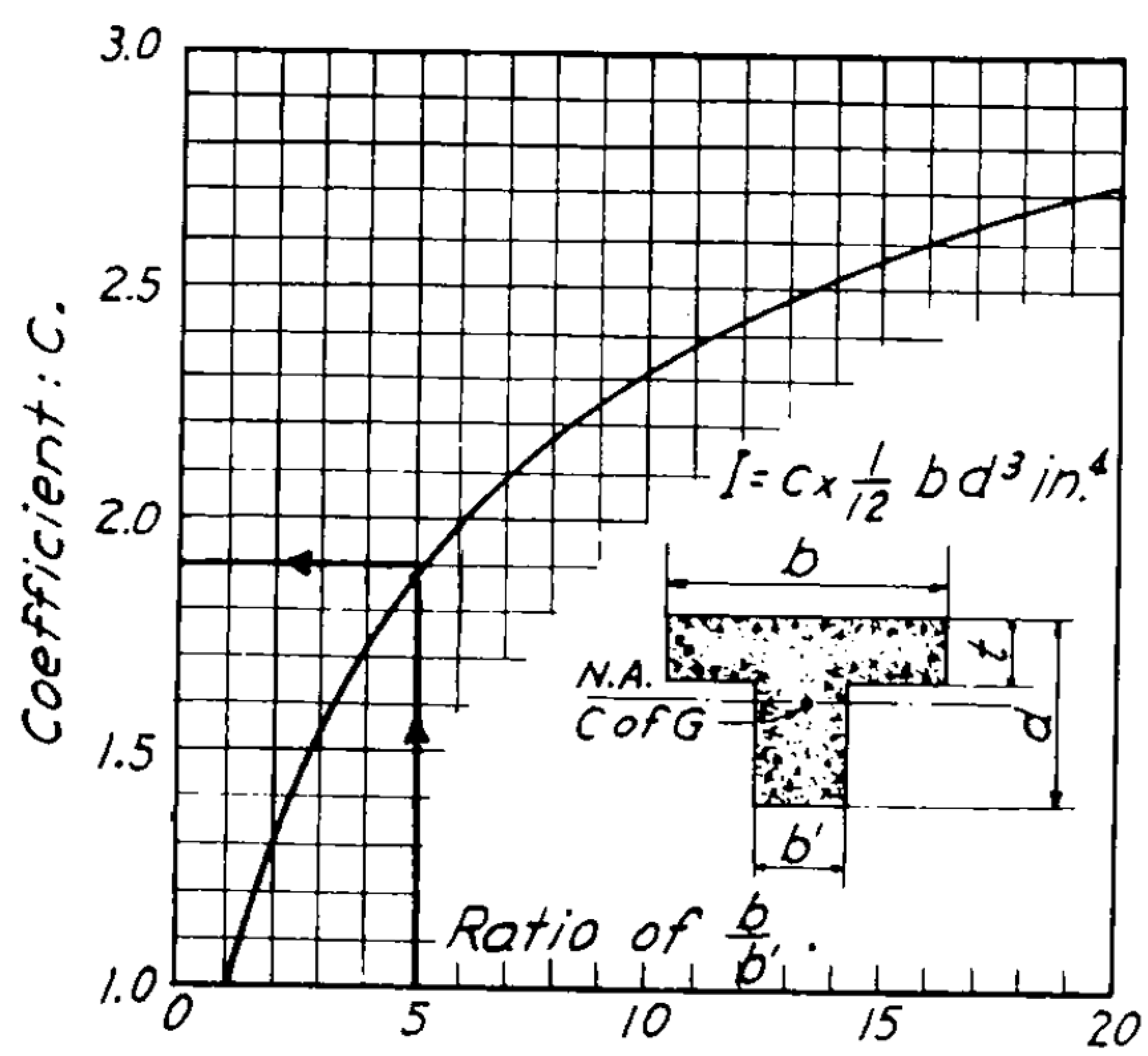
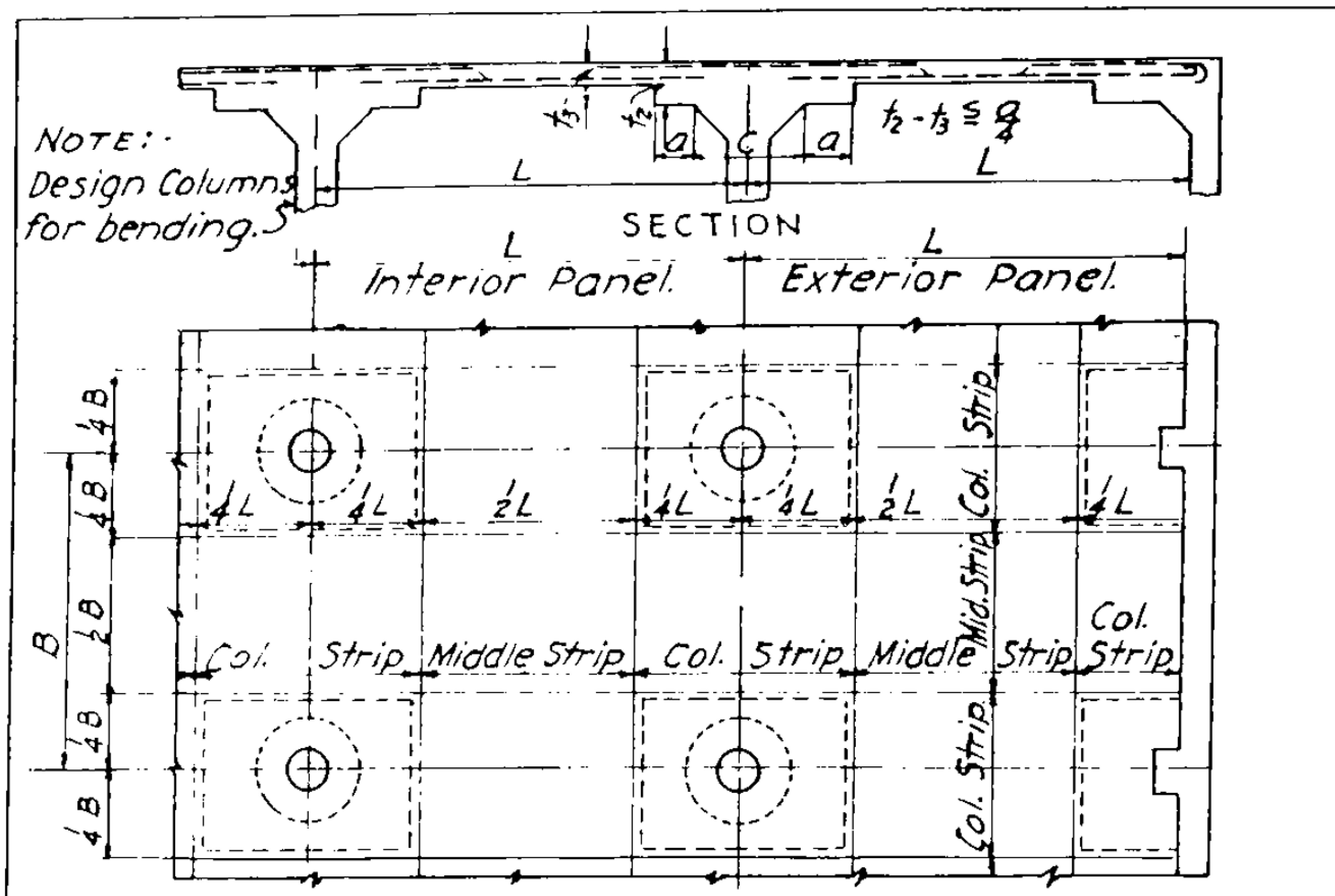


FIG. D - EFFECT OF FLANGE UPON MOMENT OF INERTIA OF "T" BEAMS.

REQUIREMENTS for PIPES: No deduction in strength need be made for iron or steel pipes or sleeves under 2" in diameter and spaced 3 diameters on centers. Embedded pipes shall not be larger than $\frac{1}{3}$ the thickness of slab, beam or wall.

STRUCTURAL — CONCRETE

TWO WAY FLAT SLAB DESIGN - 1941 A.C.I. CODE.



KEY PLAN

$M_o = 0.09W \cdot L(1-\frac{2C}{3L})^2$; $M_o = 0.09W \cdot B(1-\frac{2C}{3B})^2$

W= Total live and dead load uniformly distributed over a single panel area.

BENDING MOMENTS IN TWO WAY FLAT SLABS & PANELS.

DESCRIPTION	INTERIOR PANEL MOMENT COEFFICIENT	EXTERIOR PANEL. MOMENT COEFFICIENT
With Drop Panel. Column Strip.	Neg. -0.50 M_o Pos. +0.20 M_o	Exterior Neg.-0.45 M_o Pos. +0.25 M_o Interior Neg.-0.55 M_o
Middle Strip.	Neg.-0.15 M_o Pos.+0.15 M_o	Exterior Neg.-0.10 M_o Pos. +0.19 M_o Interior Neg.-0.165 M_o
Without Drop Panel. Column Strip.	Neg.-0.46 M_o Pos.+0.22 M_o	Exterior Neg.-0.41 M_o Pos. +0.28 M_o Interior Neg.-0.50 M_o
Middle Strip.	Neg.-0.16 M_o Pos.+0.16 M_o	Exterior Neg.-0.10 M_o Pos. +0.20 M_o Interior Neg.-0.176 M_o

BENDING MOMENTS IN PANELS WITH MARGINAL BEAMS OR WALLS.

	Marginal beams with depth greater than 1½x slab thickness; or bearing walls.		Marginal beams with depth 1½x slab thickness or less.	
(a) Load to be carried by marginal beam or wall.	Loads directly superimposed upon it plus a uniform load equal to one-quater of the total live and dead panel load		Loads directly superimposed upon it exclusive of any panel load.	
	With Drop	Without Drop	With Drop	Without Drop
(b) Moment to be used in the design of half column strip adjacent and parallel to marginal beam or wall.	Neg.-0.125 M_o Pos.+0.05 M_o	Neg.-0.115 M_o Pos.+0.055 M_o	Neg.-0.25 M_o Pos.+0.10 M_o	Neg.-0.23 M_o Pos.+0.11 M_o
(c) Negative moment to be used in design of Middle strip continuous across a beam or wall.	Neg.-0.195 M_o	Neg.-0.208 M_o	Neg.-0.15 M_o	Neg.-0.16 M_o

The bending moments are shown for the critical sections of strips in exterior panels at right angles to the discontinuous edge where the exterior support consists of reinforced concrete columns or reinforced concrete bearing walls integral with the slab, the ratio of stiffness of the support to that of the slab being at least as great as the ratio of the live load to the dead load and not less than one.

If the flat slab is supported by a wall providing restraint at the discontinuous edge use for the negative moment at the discontinuous edge of the column strip $M=-.30M_o$; and for the middle strip $M=-.25M_o$.

LIMITATIONS FOR USE OF TABLE.

1. L/B = Not more than 1.33.
2. Slab continuous over 3 or more panels in each direction.
3. The successive span length in each direction differs by not more than 20% of the shorter span.

Compression due to bending.

3/4 of the width of the strip or drop panel shall be taken as the width of the section in computing compression. For positive and negative moments tension reinforcement to be distributed over entire strip.

Thickness of Slabs.

Such as not to exceed unit stresses allowed but not to be less than L/40 with drop panels or L/36 without drop panels.

Shear

Shearing unit stress v on a vertical section t_2-1½" beyond the edge of the column capital shall not exceed:-

a- 0.03 f'c when at least 50% of the total negative reinforcement passes directly over the column capital.

b- 0.025 f'c when only 25% or less of negative reinforcement passes directly over the column capital.

c- For intermediate percentages interpolate for values of v.

d- In computing $v=\frac{V}{bjd}$, d shall be taken as t_2-1½".

e- V on a vertical section in a distance of t_3-1½" from a drop panel shall not exceed 0.03 f'c when d is taken as t_3-1½" and at least 50% of negative reinforcement in column strip is inside the width of the drop panel.

Reinforcement.

The ratio of reinforcement in any strip shall not be less than 0.0025. Spacing of bars shall not exceed 3 times thickness of slab.

General Notes.

1. The coefficients of the table may be varied by no more than 6% provided the numerical sum of the + and - moments remains unchanged.
2. For columns without a capital the distance "c" shall be taken as the diameter of the column.
3. For columns with brackets take "c" equal to twice the distance from the ℄ of column to the point where the thickness of the bracket is 1½".
4. Panels supported by marginal beams on opposite sides shall be designed as one or two way slabs.

STRUCTURAL - CONCRETE

TABLE A - MOMENT COEFFICIENTS FOR TWO WAY SLABS - A.C.I. CODE 1941

L/S		Case A	B	C	D	E	F	G	H	K
1.00	S	.500	.508	.381	.400	.285	.305	.389	.318	.250
	L	.500	.381	.508	.400	.388	.318	.285	.305	.250
1.05	S	.546	.549	.421	.437	.318	.337	.416	.344	.274
	L	.501	.378	.515	.400	.398	.322	.278	.303	.251
1.10	S	.590	.588	.460	.472	.348	.368	.442	.367	.296
	L	.503	.372	.522	.403	.410	.326	.273	.299	.252
1.15	S	.635	.624	.500	.507	.384	.400	.464	.390	.318
	L	.502	.369	.528	.402	.417	.330	.266	.295	.252
1.20	S	.680	.665	.540	.544	.420	.432	.495	.416	.340
	L	.501	.363	.530	.400	.424	.332	.261	.290	.251
1.25	S	.720	.701	.580	.576	.456	.465	.521	.438	.361
	L	.496	.355	.532	.397	.427	.333	.255	.285	.248
1.30	S	.764	.736	.618	.610	.491	.495	.548	.460	.382
	L	.489	.353	.535	.391	.432	.334	.249	.281	.245
1.35	S	.805	.773	.655	.645	.525	.524	.579	.484	.403
	L	.483	.345	.532	.386	.433	.333	.242	.276	.242
1.40	S	.847	.810	.693	.678	.560	.555	.600	.507	.424
	L	.480	.336	.530	.384	.436	.332	.236	.269	.240
1.45	S	.885	.846	.730	.709	.594	.585	.627	.530	.443
	L	.471	.330	.524	.377	.436	.328	.230	.264	.237
1.50	S	.927	.885	.765	.742	.628	.612	.657	.553	.465
	L	.462	.323	.518	.370	.436	.324	.224	.258	.232

L/S		Case A	B	C	D	E	F	G	H	K
1.55	S	.965	.920	.804	.772	.662	.644		.576	.483
	L	.453	.315	.514	.362	.436	.321		.252	.227
1.60	S	1.01	.958	.835	.803	.692	.668		.600	.502
	L	.450	.308	.506	.360	.436	.318		.246	.225
1.65	S	1.05	.995	.873	.836	.728	.698		.629	.524
	L	.440	.300	.500	.353	.427	.313		.240	.221
1.70	S	1.08	1.04	.907	.866	.758	.725		.648	.542
	L	.433	.293	.493	.347	.427	.308		.234	.217
1.75	S	1.12	1.07	.942	.900	.790	.754		.673	.561
	L	.421	.288	.490	.337	.423	.307		.230	.211
1.80	S	1.16		.978	.932	.820	.782			.583
	L	.414		.480	.331	.417	.300			.208
1.85	S	1.20		1.01	.965	.850	.810			.603
	L	.405		.472	.324	.414	.295			.203
1.90	S	1.24		1.05	.995	.880	.836			.629
	L	.399		.463	.319	.410	.290			.199
1.95	S	1.29		1.08	1.03	.914	.864			.645
	L	.391		.456	.313	.403	.286			.196
2.00	S	1.34		1.12	1.07	.940	.892			.667
	L	.378		.446	.302	.400	.280			.189

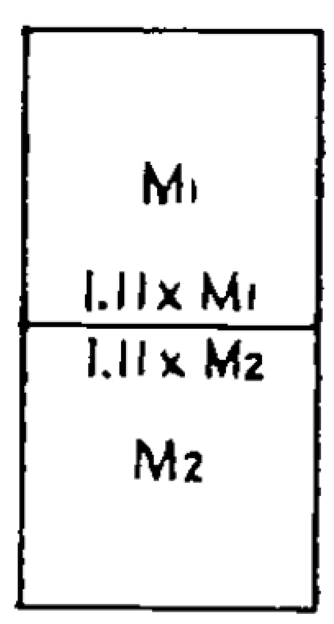
Number of Short Sides of Panel Restrained	Number of Long Sides of Panel Restrained: 0	1	2
0	A	B	G
1	C	D	H
2	E	F	K

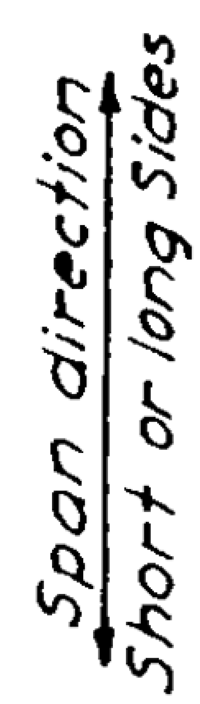
CONDITION OF RESTRAINT.

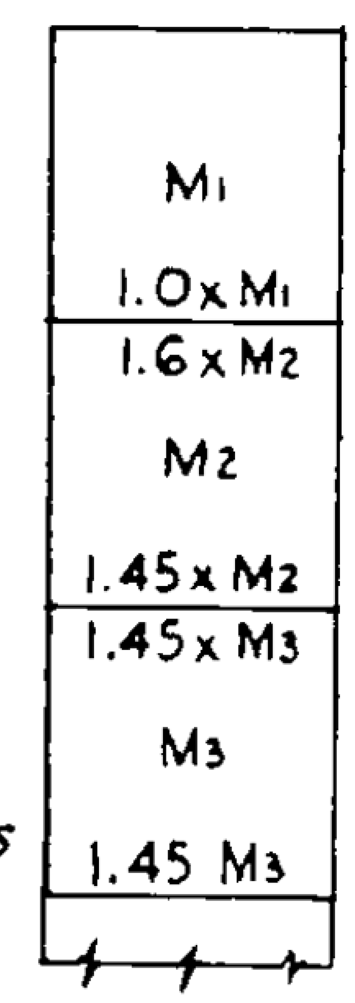
Formula:-

$$t = \frac{L+S-0.1 \cdot N}{72}$$

Where:-
t = Slab thickness - 4" minimum
N = Sum of restrained sides.
L = Long span; S = Short span in In.
M_1, M_2 & M_3 = Maximum Positive Moments in direction considered.







SKETCHES FOR NEGATIVE MOMENTS AT SUPPORTS.

The positive moment M for a slab strip one foot wide is expressed by the formula $M = WS^2c$, where M is in in.lbs.; W = total live and dead load in lbs. per sq. ft.; S = short span in feet and c = a coefficient given in table depending on condition of restraint at edges of panel and is determined as follows: Select proper case denoted by letters A to K inclusive from "Condition of Restraint." Determine ratio between long and short panel sides = L/S. The value of "c" is given in Table A at intersection of proper case and ratio L/S.

Negative moments at continuous supports are determined from the positive moments, as noted adjacent to supports in "Sketches for Negative Moments at Supports." Where the moments as determined from each of two adjacent panels differ, use the average value. Coefficients in this table apply where the larger of two adjacent values of L/S or L/S does not exceed the smaller by more than 20%. For other cases, refer to A.C.I. Code for procedure.

At non continuous supports provide hooked top bars of sectional area equal to 50% of bottom steel and extend 1/5 of clear short span into panel. Bottom steel may be reduced 25% for a distance equal to 1/4 of clear short span adjacent to continuous edges only.
Data from Republic Fireproofing Company, Inc., New York City.

STRUCTURAL - CONCRETE

TABLE A- EQUIVALENT LOAD & MOMENT COEFFICIENTS FOR BEAMS FROM TWO-WAY SLABS-A.C.I. CODE-1941.

L/S		CASE A a	A b	B a	B b	C a	C b	D a	D b	E a	E b
1.00	S	.250	1.33	.199	1.45	.302	1.24	.153	1.58	.348	1.17
	L	.250	1.33	.302	1.24	.199	1.45	.348	1.17	.153	1.58
1.05	S	.243	1.37	.190	1.50	.298	1.27	.145	1.62	.348	1.19
	L	.269	1.30	.319	1.21	.217	1.41	.362	1.15	.169	1.53
1.10	S	.236	1.41	.183	1.54	.293	1.30	.136	1.66	.352	1.21
	L	.286	1.27	.334	1.19	.233	1.37	.376	1.13	.180	1.49
1.15	S	.228	1.45	.174	1.58	.287	1.33	.129	1.68	.344	1.24
	L	.302	1.24	.349	1.17	.250	1.33	.388	1.12	.201	1.45
1.20	S	.220	1.49	.165	1.62	.280	1.37	.122	1.68	.341	1.27
	L	.317	1.21	.362	1.15	.267	1.30	.399	1.10	.216	1.41
1.25	S	.211	1.53	.157	1.65	.272	1.40	.115	1.66	.336	1.29
	L	.331	1.19	.374	1.13	.283	1.27	.408	1.09	.231	1.38
1.30	S	.203	1.57	.150	1.67	.266	1.44	.108	1.63	.330	1.32
	L	.344	1.17	.385	1.12	.295	1.25	.417	1.08	.246	1.34
1.35	S	.195	1.60	.143	1.68	.258	1.47	.102	1.56	.325	1.35
	L	.356	1.16	.395	1.11	.309	1.23	.424	1.08	.260	1.31
1.40	S	.187	1.63	.136	1.68	.249	1.51	.097	1.46	.318	1.38
	L	.367	1.14	.403	1.10	.323	1.21	.431	1.07	.273	1.29
1.45	S	.179	1.66	.129	1.66	.241	1.54	.091	1.30	.310	1.42
	L	.377	1.13	.411	1.09	.333	1.19	.437	1.06	.286	1.26
1.50	S	.171	1.68	.123	1.62	.233	1.58	.086	1.10	.302	1.45
	L	.386	1.12	.418	1.08	.345	1.17	.443	1.05	.299	1.24
1.55	S	.164	1.68	.116	1.55	.224	1.60			.293	1.48
	L	.394	1.11	.425	1.07	.356	1.16			.311	1.22
1.60	S	.157	1.68	.111	1.46	.217	1.63			.285	1.51
	L	.402	1.10	.431	1.07	.365	1.15			.322	1.21
1.65	S	.150	1.66	.105	1.34	.209	1.65			.276	1.54
	L	.409	1.09	.436	1.06	.374	1.14			.333	1.19
1.70	S	.144	1.64	.101	1.16	.200	1.68			.269	1.56
	L	.416	1.08	.441	1.06	.382	1.12			.341	1.18
1.75	S	.138	1.60	.096	1.00	.194	1.68			.261	1.59
	L	.421	1.08	.445	1.05	.389	1.11			.351	1.16
1.80	S	.132	1.52			.186	1.68			.253	1.62
	L	.427	1.07			.397	1.10			.360	1.15
1.85	S	.126	1.44			.179	1.67			.245	1.64
	L	.432	1.07			.403	1.10			.368	1.14
1.90	S	.121	1.33			.172	1.67			.237	1.65
	L	.437	1.06			.410	1.09			.376	1.13
1.95	S	.116	1.18			.165	1.65			.229	1.67
	L	.441	1.06			.416	1.08			.383	1.12
200	S	.111	1.00			.160	1.61			.222	1.68
	L	.445	1.05			.420	1.08			.389	1.11

Number Of Short Sides Of Panel Restrained.	Number Of Long Sides Of Panels Restrained: 0	1	2
0	A	B	D
1	C	A	B
2	E	C	A

CONDITION OF RESTRAINT.

NOTE:
Use coefficient "a" for determining end reactions.
Use coefficient "a×b" for determining bending moments.

The load per linear foot of beam from a two-way panel, if uniformly distributed, would equal W×S×a, where W= total live and dead load per sq. ft., S= short span in feet and a= the coefficient given in Table A. Coefficients given in S lines apply to short span beams and coefficients in L lines apply to long span beams.

Since the load on the beams is not considered uniform but varying from a Max. at center and diminishing towards each support, the equivalent uniformly distributed load for moment = W×S×a×b where coefficient "b" is also given in Table A.

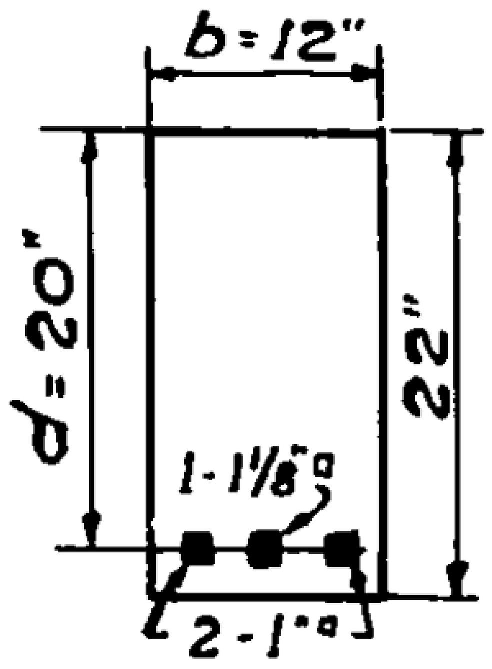
Coefficients "a" and "b" are obtained as follows: Find proper case denoted A to E incl. from "Conditions of Restraint." Determine ratio between long and short panel sides L/S. Coefficients "a" and "b" are then found at intersection of proper case and ratio L/S. Data from Republic Fireproofing Company, Inc. New York City.

STRUCTURAL - CONCRETE

EXAMPLES FOR USE OF BEAM TABLES - Pg. 1-34 to 1-37.

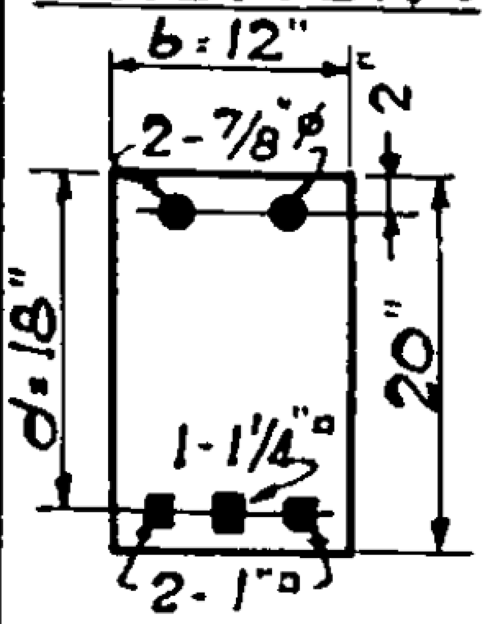
ASSUMPTIONS FOR ALL EXAMPLES: $f_s = 20{,}000$#/□", $f'_c = 3{,}000$, $n = 10$
$f_c = .45 \times 3000 = 1350$. DESIGN FOR d MINIMUM & BALANCED REINFORCEMENT.

EXAMPLE Nº 1. **Given**: Rectangular Beam, M = 90,000'#, b = 12".
Required: Effective depth "d" & Steel "A_s".
Solution: From Table A - Pg. 1-36 the minimum effective depth "d" for moment of 90,000'# required is 20" for 12" width good for 94,200'# requiring $A_s = 3.26$□". ∴ Total depth of beam = 20" + 2" = 22" and required



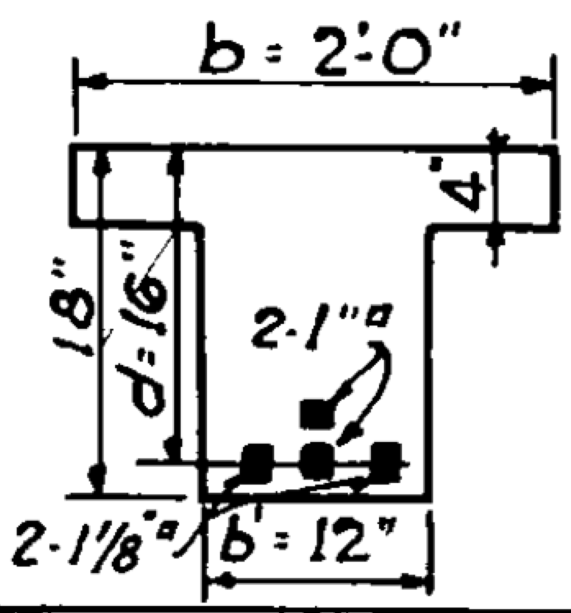
$A_s = 3.26 \times \frac{90{,}000}{94{,}200} = 3.11$□"
∴ Use 2-1"□ & 1-1⅛"□.
Referring to Table C - Pg. 1-39 these 3 Bars may be placed in 1 row for 12" wide Beam.
Check Shear and Bond Stresses.

EXAMPLE Nº 2. **Given**: Rectangular Beam with Compression Steel, M = 90,000'#, depth = 20", b = 12".
Required: Tension Steel A_s and Compr. Steel A'_s.
Solution: From Table A - Pg. 1-36 the minimum effective depth "d" for moment of 90,000'# required is 18" for 12" width good for 76,300'# requiring $A_s = 2.94$□". ∴ The difference in moments = 90,000 - 76,300 = 13,700'#, which must be taken up by Compression Steel. From Table A - Pg. 1-36 Column for 1□" Compression Steel gives moment of M = 11.7'#. ∴ Required Compression steel $A'_s = \frac{13.7}{11.7} = 1.17$□". ∴ Use 2-⅞"ϕ.
This Compression Steel must be balanced by additional Tension Steel.
Referring to Table C - Pg. 1-39 these 3 Bars may be placed in 1 row for 12" wide Beam.



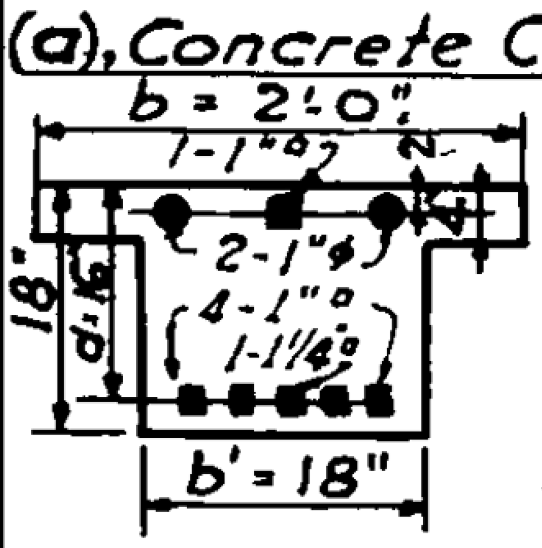
Check Shear and Bond Stresses.

EXAMPLE Nº 3. **Given**: T-Beam, M = 105,000'#, slab thickness 4", width b = 2'-0", width of stem b' = 12".
Required: Depth of Beam "d", Steel A_s.
Solution: From Table A - Pg. 1-36 value of moment to be carried by 12" of width $M = \frac{105{,}000}{2} = 52{,}500$'#. In same Table, in Column for 4" Slabs, the minimum effective depth "d" for moment of 52,500'# is 16" for 12" width & is good for 53,300'# requiring $A_s = 2.23$□". ∴ Total depth of Beam = 16" + 2 = 18" & required $A_s = \frac{105{,}000}{53{,}300} \times 2.23 = 4.4$□". ∴ Use 2-1"□ & 2-1⅛"□. Referring to Table C - Pg. 1-39 place 2-1⅛"□ in bottom layer & 1-1"□ in bottom layer & 1-1"□ in 2nd layer.



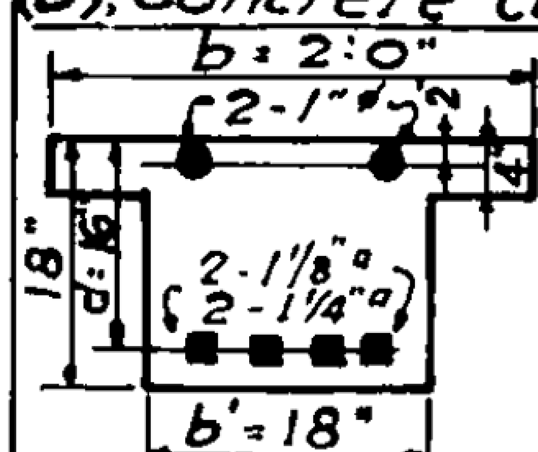
EXAMPLE Nº 4. **Given**: T-Beam with Compression Steel. Total Moment M = 132,000'#, Slab thickness 4", b = 2'-0", d = 16".
Required: Tension and Compression reinforcement.

(a). Concrete Compression in Stem neglected.



Solution: From Table A - Pg. 1-36 in Col. for 4" Slab and d = 16" find M = 53,300'# and $A_s = 2.23$□". ∴ The difference in moments $M_c = 132{,}000 - 2 \times 53{,}300 = 25{,}400$'# which must be taken up by Compression Steel. From Table A - Pg. 1-36 in Column for 1□" Compression Steel M = 9,800'# for d = 16".
Total Compression Steel required $A'_s = \frac{25{,}400}{9{,}800} = 2.6$□". ∴ Use 2-1"ϕ & 1-1"□.
This Compression Steel must be balanced by additional Tension Steel. Referring to last Column in Table A - Pg. 1-36, $A_T = .42$□" per 1□" of Compression Steel.
Total Tension Steel $A_s = 2.23 \times 2 + .42 \times 2.6 = 5.55$□"
∴ Use 4-1"□ & 1-1¼"□.
Referring to Table C - Pg. 1-39 minim. width of Stem for 4-1"□ & 1-1¼"□ = b' = 17½". Use 18" and Bars may be placed in 1 row for 18" wide Beam.
Check Shear and Bond Stresses.

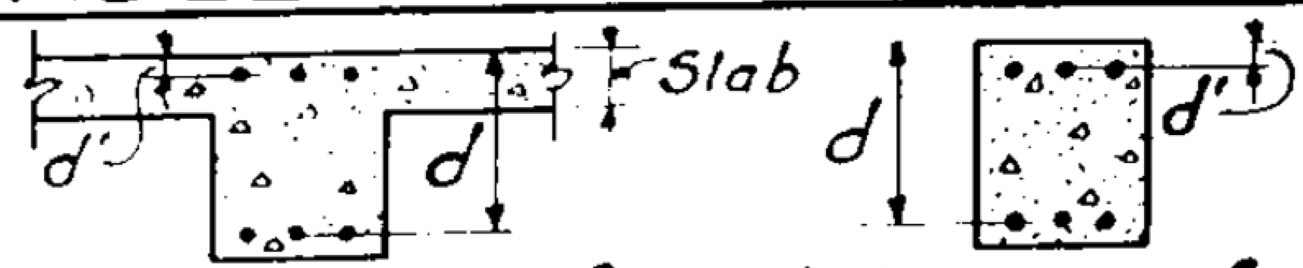
(b). Concrete Compression in Stem Considered.



Solution: From Table A - Pg. 1-36 in Col. for 4" Slab and d = 16" find M = 53,300'# and $A_s = 2.23$□". Width of slab 24" - 18" = 6"
M = 53,300 × 6/12 = 26,700'#,
$A'_s = 2.23 \times 6/12 = 1.12$□"
From Table A - Pg. 1-36 in Rectg. Beam Col. and d = 16" find M = 60,300'# requiring Steel $A_s = 2.61$□".
∴ For 18" wide Beam and 16" effective depth M = 60,300 × 18/12 = 90,500'#,
$A_s = 2.61 \times 18/12 = 3.92$□"
The difference in moments $M_c = 132{,}000 - 26{,}700 - 90{,}500 = 14{,}800$'#. From Table A - Pg. 1-36 in Col. for 1□" Compr. Steel M = 9,800'# for d = 16".
Total Compr. Steel required $A_s = \frac{14{,}800}{9{,}800} = 1.5$□".
This Compression Steel must be balanced by additional Tension Steel. Referring to Table A - Pg 1-36 $A_T = .42$□". ∴ Use 2-1"ϕ. Total Tension Steel requd. $A_s = 1.12 + 3.92 + .42 \times 1.5 = 5.67$□". ∴ Use 2-1⅛"□ & 2-1¼"□ and Bars may be placed in 1 row for 18" wide Beam. Check Shear & Bond Stresses.

STRUCTURAL - CONCRETE

TABLE A - RESISTING MOMENTS OF CONCRETE BEAMS.*



$f_s = 20{,}000 \text{\#}/\square''$ $f_c = 900$

$f_c' = 2{,}000$ $n = 15$ $R = 157.0$

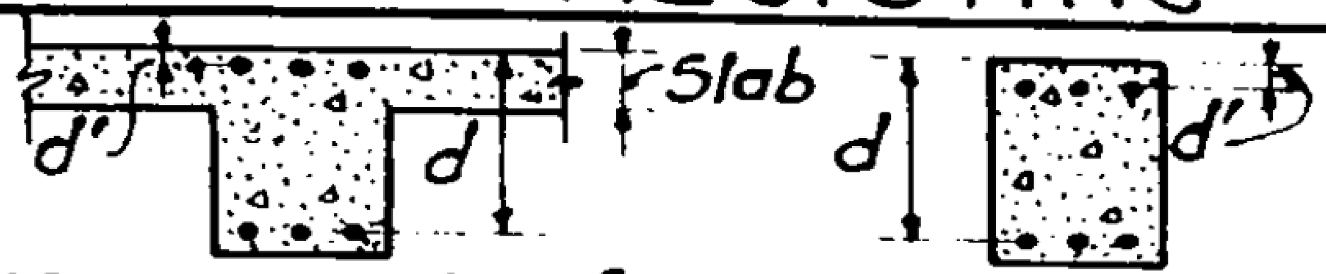
M = Moment of resistance of beam one foot wide in 1000 foot lbs.
A_s = Tensile steel area in sq. inches for moment M.
A_T = Sq. in. additional tensile steel for each $1\square''$ compression steel.

d	TEE BEAMS FOR SLAB THICKNESSES SHOWN												RECTANGULAR BEAM		MOMENTS OF $1\square''$ OF COMPRESSIVE ST.		A_T FOR $d' = 2''$
	2" SLAB		2½" SLAB		3" SLAB		4" SLAB		5" SLAB		6" SLAB						
	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	$d' = 1½''$	$d' = 2''$	
6"	5.5	.63											5.7	.65	1.8	.73	.11
6½	6.4	.67											6.6	.71	2.3	1.1	.15
7	7.2	.70	7.6	.75									7.7	.76	2.7	1.5	.18
7½	8.0	.72	8.6	.79									8.8	.82	3.2	2.0	.21
8	8.9	.74	9.7	.83	9.9	.87							10.0	.87	3.7	2.4	.24
8½	9.7	.76	10.2	.86	11.2	.91							11.3	.92	4.1	2.9	.26
9	10.6	.78	11.8	.88	12.4	.95							12.7	.98	4.6	3.3	.28
9½	11.5	.80	12.8	.91	13.7	.99							14.2	1.03	5.1	3.8	.30
10	12.3	.81	13.9	.93	14.9	1.02	15.7	1.09					15.7	1.09	5.6	4.2	.32
10½	13.2	.83	15.0	.95	16.2	1.05	17.3	1.14					17.3	1.14	6.1	4.7	.34
11	14.1	.84	16.0	.97	17.4	1.07	18.9	1.19					19.0	1.20	6.6	5.2	.35
11½	15.0	.85	17.1	.99	18.7	1.10	20.5	1.23					20.8	1.25	7.1	5.7	.36
12	15.8	.86	18.2	1.00	20.0	1.12	22.1	1.27					22.6	1.31	7.6	6.2	.37
12½	16.7	.86	19.3	1.02	21.3	1.14	23.8	1.31					24.5	1.36	8.1	6.7	.38
13	17.6	.87	20.4	1.03	22.6	1.16	25.4	1.34	26.5	1.41			26.5	1.41	8.6	7.1	.39
13½	18.5	.88	21.4	1.04	23.9	1.18	27.1	1.37	28.5	1.46			28.7	1.47	9.1	7.6	.40
14	19.4	.89	22.5	1.05	25.1	1.19	28.7	1.39	30.5	1.50			30.8	1.52	9.6	8.1	.41
15	21.1	.90	24.7	1.07	27.7	1.22	32.1	1.45	34.6	1.58	35.3	1.63	35.3	1.63	10.7	9.1	.42
16	22.9	.91	26.9	1.09	30.4	1.24	35.5	1.49	38.7	1.65	40.0	1.73	40.2	1.74		10.1	.43
17	24.7	.92	29.2	1.11	33.0	1.27	39.0	1.53	42.8	1.72	44.8	1.82	45.4	1.85		11.2	.45
18	26.5	.93	31.4	1.12	35.6	1.29	42.4	1.56	47.0	1.77	49.8	1.90	50.9	1.96		12.2	.46
19	28.3	.94	33.6	1.13	38.3	1.30	45.9	1.60	51.3	1.82	54.7	1.97	56.7	2.07		13.2	.47
20	30.0	.95	35.8	1.14	40.9	1.32	49.3	1.62	55.5	1.86	59.7	2.04	62.8	2.18		14.2	.47
21	31.8	.95	38.0	1.15	43.6	1.33	52.8	1.65	59.8	1.90	64.7	2.09	69.2	2.28		15.2	.48
22	33.6	.96	40.3	1.16	46.2	1.35	56.3	1.67	64.0	1.94	69.7	2.14	76.0	2.39		16.3	.49
23	35.4	.96	42.5	1.17	48.9	1.36	59.8	1.69	68.3	1.97	74.8	2.19	83.0	2.50		17.3	.49
24	37.2	.97	44.7	1.18	51.5	1.37	63.3	1.71	72.7	2.00	79.9	2.23	90.4	2.61		18.3	.50
25	38.8	.97	46.9	1.18	54.2	1.38	66.9	1.72	76.9	2.02	85.0	2.27	98.1	2.73		19.3	.51
26			49.2	1.19	56.9	1.39	70.4	1.75	81.4	2.06	90.2	2.31	106.1	2.83		20.4	.51
27			51.4	1.20	59.5	1.40	74.0	1.77	86.0	2.08	94.8	2.35	114.5	2.95		21.5	.51
28			53.7	1.20	62.2	1.40	77.5	1.78	90.2	2.10	100.6	2.38	123.1	3.05		22.5	.52
29			55.5	1.20	64.8	1.41	80.7	1.79	94.2	2.12	105.0	2.41	132.0	3.17		23.5	.52
30			58.2	1.21	67.6	1.42	84.6	1.80	99.0	2.14	111.0	2.44	141.3	3.26		24.5	.53
32					73.0	1.43	91.6	1.82	107.8	2.18	121.3	2.48	160.8	3.48		26.6	.53
34					78.3	1.44	98.7	1.84	116.6	2.21	131.9	2.53	181.5	3.70		28.7	.54
36					83.6	1.45	105.8	1.86	125.4	2.23	142.5	2.57	203.5	3.92		30.8	.54
38							113.0	1.88	134.2	2.26	152.9	2.60	226.7	4.13		32.9	.55
40							120.1	1.89	143.1	2.28	163.5	2.64	251.2	4.35		34.9	.55
44									160.9	2.32	184.9	2.69	303.9	4.79		39.1	.56
48									178.7	2.35	206.0	2.74	361.7	5.22		43.3	.56

* Adapted from Singleton, Manual of Structural Design, H.M. Ives & Sons.
See Pg. 1-33 for Examples for use of Beam Tables.

STRUCTURAL - CONCRETE

TABLE A - RESISTING MOMENTS OF CONCRETE BEAMS.*



$f_s = 20{,}000$ #/□" $f_c = 1125$

$f'_c = 2{,}500$ $n = 12$ $R = 196.2$

M = Moment of resistance of beam one foot wide in 1000 foot lbs.
A_s = Tensile steel area in sq. inches for moment M.
A_T = Sq. in. additional tensile steel for each 1□" compression steel.

d	TEE BEAMS FOR SLAB THICKNESSES SHOWN												RECTANGULAR BEAM		MOMENTS OF 1□" OF COMPRESSIVE ST.		A_T FOR d'=2"
	2" SLAB		2½" SLAB		3" SLAB		4" SLAB		5" SLAB		6" SLAB						
	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	d'=1½"	d'=2"	
6"	6.9	.79											7.1	.82	1.8	.7	.11
6½	7.9	.84											8.3	.88	2.2	1.1	.15
7	9.0	.87	9.5	.94									9.6	.95	2.7	1.5	.18
7½	10.1	.90	10.8	.99									11.0	1.02	3.1	2.0	.21
8	11.1	.93	12.1	1.04	12.3	1.09							12.6	1.09	3.6	2.4	.24
8½	12.2	.95	12.8	1.08	13.9	1.14							14.2	1.16	4.0	2.8	.26
9	13.2	.98	14.7	1.10	15.5	1.19							15.9	1.22	4.5	3.2	.28
9½	14.3	1.00	16.0	1.13	17.1	1.23							17.7	1.29	5.0	3.7	.30
10	15.4	1.02	17.3	1.16	18.7	1.27	19.6	1.36					19.6	1.36	5.5	4.2	.31
10½	16.5	1.04	18.7	1.19	20.2	1.31	21.6	1.43					21.6	1.43	6.0	4.7	.33
11	17.6	1.05	20.0	1.21	21.8	1.34	23.6	1.49					23.7	1.50	6.5	5.1	.34
11½	18.7	1.06	21.4	1.23	23.4	1.37	25.6	1.54					26.0	1.56	7.0	5.6	.35
12	19.8	1.07	22.7	1.25	25.0	1.40	27.6	1.59					28.3	1.63	7.5	6.0	.36
12½	209	1.08	24.1	1.27	26.6	1.43	29.7	1.64					30.7	1.70	8.0	6.5	.37
13	22.0	1.09	25.4	1.29	28.2	1.45	31.8	1.68	33.1	1.76			33.2	1.77	8.5	7.0	.38
13½	23.1	1.10	26.8	1.31	29.8	1.47	33.8	1.71	35.6	1.82			35.9	1.84	9.0	7.5	.39
14	24.2	1.11	28.2	1.32	31.4	1.49	35.9	1.74	38.1	1.87			38.5	1.90	9.5	8.0	.40
15	26.4	1.13	30.9	1.34	34.7	1.53	40.1	1.80	43.2	1.97	44.2	2.04	44.2	2.04	10.5	9.0	.41
16	28.6	1.14	33.7	1.36	37.9	1.56	44.4	1.86	48.3	2.07	50.0	2.16	50.2	2.18		10.0	.43
17	30.9	1.15	36.5	1.38	41.3	1.59	48.7	1.91	53.5	2.15	56.1	2.27	56.7	2.31		11.0	.44
18	33.1	1.17	39.2	1.40	44.5	1.61	53.0	1.95	58.7	2.21	62.2	2.36	63.6	2.45		12.0	.45
19	35.3	1.18	42.0	1.42	47.8	1.63	57.3	1.99	64.1	2.27	68.3	2.45	70.8	2.58		13.0	.46
20	37.5	1.19	44.8	1.43	51.1	1.65	61.7	2.02	69.4	2.32	74.6	2.54	78.5	2.72		14.0	.47
21	39.8	1.19	47.5	1.44	54.5	1.66	66.1	2.06	74.7	2.37	80.8	2.61	86.5	2.86		15.0	.47
22	42.0	1.20	50.4	1.46	57.8	1.68	70.4	2.09	80.0	2.42	87.1	2.67	95.0	2.99		16.0	.48
23	44.2	1.21	53.0	1.47	61.0	1.70	74.8	2.12	85.4	2.46	93.5	2.73	103.8	3.13		17.0	.49
24	46.5	1.21	55.9	1.48	64.4	1.71	79.2	2.14	90.9	2.50	99.9	2.79	113.0	3.26		18.0	.49
25	48.8	1.22	58.8	1.48	67.5	1.72	83.8	2.16	96.3	2.54	106.3	2.84	122.5	3.39		19.0	.50
26			61.6	1.49	71.0	1.73	87.9	2.18	101.8	2.57	112.7	2.88	132.7	3.54		20.0	.50
27			64.2	1.50	74.4	1.74	92.4	2.20	107.4	2.60	118.7	2.93	142.9	3.67		21.0	.51
28			67.1	1.50	77.8	1.75	96.8	2.21	112.8	2.62	125.7	2.97	153.8	3.81		22.1	.51
29			69.5	1.50	81.1	1.76	101.8	2.23	118.5	2.65	132.0	3.00	164.9	3.95		23.1	.51
30			72.8	1.51	84.3	1.77	105.7	2.24	123.7	2.67	138.8	3.04	176.6	4.08		24.1	.52
32					91.1	1.79	114.5	2.27	134.7	2.72	151.7	3.10	200.9	4.35		26.1	.52
34					97.8	1.80	123.4	2.30	145.7	2.76	164.9	3.15	226.8	4.62		28.2	.53
36					104.5	1.81	132.3	2.32	156.7	2.79	178.1	3.20	254.3	4.90		30.2	.53
38							141.3	2.34	167.7	2.81	191.2	3.25	283.4	5.17		32.3	.54
40							150.1	2.36	178.9	2.85	204.4	3.30	314.0	5.44		34.3	.54
44									201.1	2.90	231.2	3.37	379.9	5.98		38.4	.55
48									212.2	2.92	257.2	3.42	452.1	6.53		42.5	.55

* Adapted from Singleton, Manual of Structural Design, H.M. Ives & Sons.
See Pg. 1-33 for Examples for use of Beam Tables.

STRUCTURAL - CONCRETE

TABLE A - RESISTING MOMENTS OF CONCRETE BEAMS.*

slab d' d d d'

$f_s = 20,000$ #/□" $f_c = 1350$

$f_c' = 3,000$ $n = 10$ $R = 235.6$

M = Moment of resistance of beam one foot wide in 1000 foot lbs.
A_s = Tensile steel area in sq. inches for moment M.
A_T = Sq. in. additional tensile steel for each 1□" compression steel.

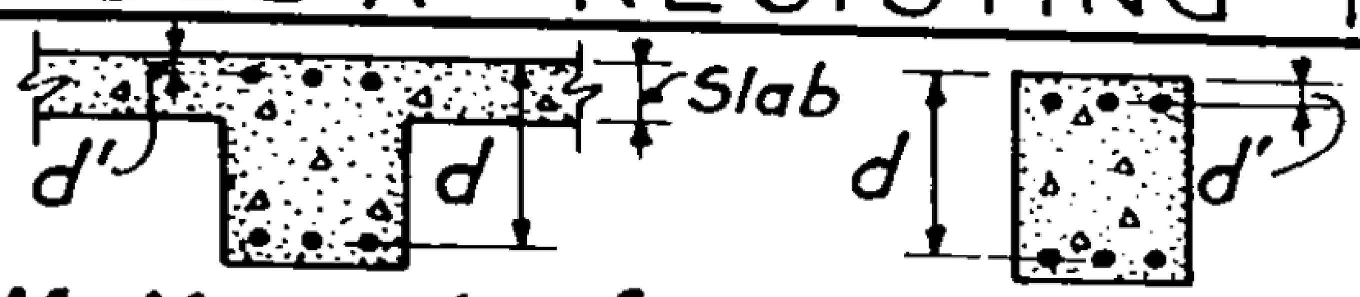
d	TEE BEAMS FOR SLAB THICKNESSES SHOWN												RECTANGULAR BEAM		MOMENTS OF 1□" OF COMPRESSIVE ST.		A_T FOR d'=2"
	2" SLAB		2½" SLAB		3" SLAB		4" SLAB		5" SLAB		6" SLAB						
	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	d'=1½"	d'=2"	
6"	8.3	.94											8.5	.98	1.7	.7	.11
6½	9.5	1.01											9.9	1.06	2.2	1.1	.15
7	10.8	1.05	11.4	1.12									11.5	1.14	2.6	1.5	.18
7½	12.1	1.08	12.9	1.18									13.2	1.22	3.1	1.9	.21
8	13.3	1.11	14.5	1.24	14.8	1.30							15.1	1.31	3.5	2.3	.23
8½	14.6	1.14	15.3	1.29	16.7	1.36							17.0	1.39	4.0	2.8	.25
9	15.9	1.17	17.6	1.33	18.6	1.42							19.1	1.47	4.4	3.2	.27
9½	17.2	1.20	19.2	1.37	20.5	1.47							21.3	1.55	4.9	3.7	.29
10	18.5	1.22	20.8	1.40	22.4	1.52	23.6	1.63					23.5	1.63	5.4	4.1	.31
10½	19.8	1.24	22.4	1.42	24.2	1.57	25.9	1.71					26.0	1.71	5.9	4.6	.32
11	21.1	1.26	24.0	1.45	26.1	1.61	28.3	1.78					28.5	1.80	6.4	5.0	.33
11½	22.4	1.27	25.7	1.48	28.0	1.65	30.7	1.84					31.1	1.88	6.8	5.5	.35
12	23.7	1.28	27.2	1.50	30.0	1.68	33.2	1.90					33.9	1.96	7.3	5.9	.36
12½	25.1	1.29	28.9	1.53	31.9	1.71	35.6	1.96					36.8	2.04	7.8	6.4	.37
13	26.4	1.30	30.5	1.55	33.8	1.74	38.1	2.01	39.8	2.12			39.8	2.12	8.3	6.9	.38
13½	27.7	1.31	32.2	1.57	35.7	1.77	40.6	2.05	42.7	2.19			43.0	2.20	8.8	7.4	.39
14	29.0	1.32	33.8	1.58	37.7	1.80	43.1	2.09	45.7	2.25			46.2	2.28	9.3	7.8	.39
15	31.7	1.34	37.1	1.61	41.6	1.84	48.2	2.17	51.8	2.37	53.0	2.45	53.0	2.45	10.3	8.8	.41
16	34.4	1.36	40.4	1.64	45.5	1.88	53.3	2.23	58.0	2.49	60.0	2.59	60.3	2.61		9.8	.42
17	37.1	1.38	43.7	1.66	49.5	1.90	58.4	2.30	64.2	2.58	67.3	2.73	68.1	2.77		10.8	.43
18	39.7	1.40	47.0	1.68	53.5	1.93	63.5	2.35	70.5	2.65	74.6	2.85	76.3	2.94		11.7	.44
19	42.4	1.42	50.3	1.70	57.4	1.96	68.8	2.39	76.9	2.72	82.0	2.96	85.0	3.10		12.7	.45
20	45.1	1.43	53.7	1.71	61.3	1.98	74.0	2.43	83.2	2.79	89.5	3.06	94.2	3.26		13.7	.46
21	47.7	1.44	57.0	1.73	65.4	2.00	79.3	2.47	89.7	2.85	97.0	3.14	103.8	3.43		14.7	.46
22	50.5	1.45	60.5	1.75	69.4	2.02	84.5	2.51	96.0	2.90	104.6	3.21	114.0	3.59		15.7	.47
23	53.0	1.46	63.7	1.76	73.3	2.04	89.7	2.54	102.5	2.95	112.2	3.28	124.6	3.75		16.7	.48
24	55.8	1.47	67.2	1.77	77.2	2.06	95.0	2.57	109.0	3.00	119.9	3.34	135.6	3.92		17.7	.48
25	58.8	1.47	70.6	1.78	81.3	2.07	100.0	2.59	115.6	3.04	127.5	3.38	147.5	4.08		18.7	.49
26			73.9	1.78	85.3	2.08	105.5	2.62	122.1	3.08	135.3	3.46	159.2	4.24		19.7	.49
27			77.2	1.79	89.3	2.09	110.8	2.64	128.3	3.12	142.2	3.50	172.0	4.41		20.7	.50
28			80.5	1.80	93.4	2.10	116.2	2.66	135.3	3.15	150.8	3.55	184.6	4.57		21.7	.50
29			84.1	1.81	97.6	2.11	121.9	2.68	141.3	3.18	158.1	3.60	198.5	4.74		22.7	.50
30			87.4	1.82	101.3	2.12	126.9	2.70	148.4	3.21	166.5	3.64	211.9	4.90		23.7	.51
32					109.4	2.14	137.4	2.73	161.7	3.27	182.0	3.72	241.1	5.22		25.7	.51
34					117.4	2.16	148.1	2.76	174.9	3.32	197.8	3.80	272.2	5.55		27.7	.52
36					125.4	2.17	158.8	2.79	188.0	3.36	213.7	3.86	305.2	5.88		29.7	.52
38							169.6	2.82	201.2	3.39	229.4	3.91	340.0	6.20		31.7	.53
40							180.1	2.84	214.6	3.42	245.3	3.96	376.8	6.53		33.7	.53
44									241.3	3.48	277.4	4.04	455.9	7.18		37.7	.54
48									268.1	3.53	309.1	4.11	542.5	7.83		41.8	.55

*Adapted from Singleton, Manual of Structural Design, H.M. Ives & Sons.

See Pg. 1-33 for Examples for use of Beam Tables.

STRUCTURAL - CONCRETE

TABLE A - RESISTING MOMENTS OF CONCRETE BEAMS.*



$f_s = 20,000$ #/□" $f_c = 1700$

$f'_c = 3,750$ $n = 8$ $R = 298.0$

M = Moment of resistance of beam one foot wide in 1000 foot lbs.
A_s = Tensile steel area in sq. inches for moment M.
A_T = Sq. in. additional tensile steel for each □" compression steel.

d	TEE BEAMS FOR SLAB THICKNESSES SHOWN												RECTANGULAR BEAM		MOMENTS OF □" OF COMPRESSIVE ST.		A_T FOR d'=2"
	2" SLAB		2½" SLAB		3" SLAB		4" SLAB		5" SLAB		6" SLAB						
	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	d'=1½"	d'=2"	
6"	10.5	1.22											10.7	1.24	1.6	.7	.11
6½	12.0	1.26											12.6	1.34	2.1	1.1	.15
7	13.5	1.30	14.4	1.43									14.6	1.44	2.6	1.5	.18
7½	15.2	1.35	16.4	1.50									16.7	1.55	3.0	1.9	.21
8	16.7	1.39	18.3	1.57	19.0	1.66							19.1	1.66	3.5	2.3	.23
8½	18.4	1.43	20.2	1.64	21.2	1.73							21.5	1.76	3.9	2.7	.25
9	19.8	1.46	22.2	1.70	23.5	1.80							24.1	1.87	4.4	3.1	.27
9½	21.5	1.49	24.2	1.75	25.8	1.87							26.8	1.96	4.8	3.6	.29
10	23.3	1.52	26.2	1.79	28.2	1.93							29.8	2.07	5.3	4.0	.30
10½	25.0	1.55	28.3	1.82	30.6	1.99							32.8	2.17	5.8	4.4	.32
11	26.8	1.58	30.4	1.85	33.0	2.05	35.9	2.28					36.0	2.27	6.3	4.9	.33
11½	28.3	1.60	32.4	1.88	35.4	2.08	38.7	2.34					39.3	2.38	6.7	5.4	.34
12	30.0	1.62	34.5	1.90	37.8	2.12	41.9	2.41					42.9	2.48	7.2	5.8	.35
12½	31.5	1.63	36.5	1.92	40.2	2.15	44.9	2.48					46.6	2.59	7.7	6.3	.36
13	33.2	1.65	38.6	1.94	42.5	2.18	48.2	2.55					50.4	2.69	8.2	6.8	.37
13½	35.0	1.67	40.8	1.96	44.8	2.22	51.2	2.62					54.2	2.79	8.6	7.2	.38
14	36.6	1.69	42.9	1.99	47.5	2.27	54.3	2.69	57.5	2.88			58.4	2.90	9.1	7.7	.39
15	39.9	1.71	47.0	2.01	52.4	2.31	60.7	2.76	65.5	3.01			67.2	3.11	10.1	8.7	.40
16	43.4	1.73	50.8	2.04	57.4	2.34	67.0	2.82	73.0	3.13	76.2	3.37	76.3	3.31		9.6	.41
17	46.8	1.75	55.0	2.07	62.4	2.37	73.4	2.88	81.0	3.23	85.2	3.49	86.0	3.51		10.6	.42
18	50.1	1.76	59.3	2.10	67.4	2.40	79.5	2.94	89.0	3.32	94.2	3.61	96.5	3.72		11.5	.43
19	53.0	1.77	63.5	2.12	72.0	2.43	86.3	3.00	96.4	3.40	103.5	3.72	107.5	3.93		12.5	.44
20	56.9	1.78	67.8	2.14	77.2	2.46	93.6	3.05	104.8	3.48	112.5	3.83	119.2	4.14		13.4	.45
21	60.5	1.79	71.4	2.16	82.4	2.49	99.6	3.09	112.6	3.56	124.0	3.93	131.2	4.34		14.4	.46
22	63.5	1.80	76.0	2.18	87.3	2.51	106.5	3.13	120.8	3.63	131.5	4.02	144.0	4.54		15.4	.46
23	66.6	1.81	79.3	2.20	92.0	2.53	113.0	3.17	129.0	3.70	141.0	4.11	157.5	4.75		16.4	.47
24	70.2	1.82	84.0	2.22	97.4	2.55	119.8	3.21	137.0	3.77	151.0	4.20	171.8	4.96		17.3	.47
25			88.7	2.23	102.5	2.57	126.1	3.25	145.5	3.83	160.6	4.28	186.3	5.18		18.3	.48
26			93.3	2.24	106.4	2.59	132.5	3.28	153.5	3.88	169.2	4.35	201.5	5.38		19.3	.48
27			97.7	2.25	112.0	2.61	139.0	3.31	162.2	3.92	178.8	4.42	217.3	5.59		20.3	.49
28			101.0	2.26	117.3	2.63	146.5	3.33	170.8	3.96	188.8	4.48	233.3	5.78		21.3	.49
29			105.8	2.27	122.5	2.65	152.8	3.35	178.3	4.00	199.0	4.54	250.5	5.99		22.2	.49
30			110.4	2.28	127.8	2.67	159.3	3.37	187.2	4.03	209.7	4.59	268.2	6.22		23.2	.50
32					137.5	2.70	173.0	3.41	203.0	4.09	230.0	4.67	304.0	6.60		25.1	.50
34					146.8	2.72	187.5	3.45	220.0	4.15	250.0	4.75	345.5	7.06		27.1	.51
36					158.0	2.74	200.0	3.49	237.5	4.21	270.0	4.82	387.0	7.47		29.1	.51
38							212.0	3.53	252.5	4.27	288.8	4.89	429.0	7.85		31.0	.52
40							227.2	3.57	270.4	4.32	308.8	4.96	476.8	8.26		33.0	.52
44							254.0	3.62	304.2	4.38	349.0	5.06	577.0	9.15		37.0	.53
48							283.0	3.67	337.0	4.43	390.0	5.16	685.0	9.92		41.0	.54

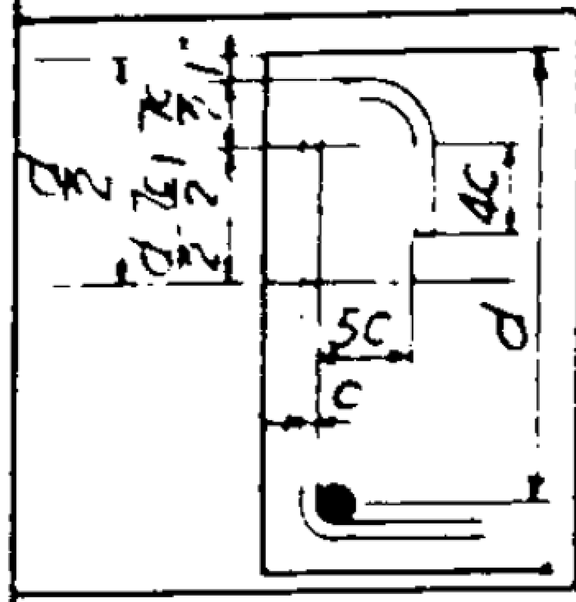
* See Pg. 1-33 for Examples for use of Beam Tables.

STRUCTURAL - CONCRETE

STIRRUP DATA
WEB REINFORCEMENT - A.C.I.

TABLE A - MINIMUM DEPTHS FOR EMBEDMENT OF VERTICAL HOOKED STIRRUPS.

Deformed Bars: $d = (f_v - 10{,}000)\frac{10c}{f_c'} + 7c + 2$ *Plain Bars:* $d = (f_v - 10{,}000)\frac{12.5c}{f_c'} + 7c + 2$



f_c'	Size - f_v = 20,000#/□" Plain. 1/4"ϕ	Deformed. 1/4"ϕ	3/8"ϕ	1/2"ϕ	5/8"ϕ	Size - f_v = 18,000#/□" Plain. 1/4"ϕ	Deformed. 1/4"ϕ	3/8"ϕ	1/2"ϕ	5/8"ϕ	Size - f_v = 16,000#/□" Plain. 1/4"ϕ	Deformed. 1/4"ϕ	3/8"ϕ	1/2"ϕ	5/8"ϕ
2,000	19.4	16.3	23.4	30.5	37.6	16.3	13.8	19.6	25.5	31.4	13.1	11.3	15.9	20.5	25.1
2,500	16.3	13.8	19.6	25.5	31.4	13.8	11.8	16.6	21.5	26.4	11.3	9.8	13.6	17.5	21.4
3,000	14.2	12.1	17.1	22.2	27.2	12.1	10.4	14.6	18.8	23.0	10.0	8.8	12.1	15.5	18.9
3,750	12.1	10.4	14.6	18.8	23.0	10.4	9.1	12.6	16.2	19.7	8.8	7.8	10.6	13.5	16.4
Stirrup Value in Pounds.	2000	2000	4400	8000	12400	1,800	1,800	3,960	7,200	11,160	16,00	1,600	3,520	6,400	9,920

TABLE B - FORMULAS FOR "N" FOR UNIFORMLY LOADED BEAMS (f_v = 20,000#/□")*

Size Of Stirrups.	1/4"ϕ U	3/8"ϕ U	1/2"ϕ U	5/8"ϕ U
"N"† Theoretical Number Of Stirrups In One End Of Beam.	$\frac{(V-V_c)\cdot a}{3.4\,d}$	$\frac{(V-V_c)\cdot a}{7.7\,d}$	$\frac{(V-V_c)\cdot a}{13.7\,d}$	$\frac{(V-V_c)\cdot a}{21.5\,d}$

†Increase "N" proportionately for f_v less than 20,000#/□".

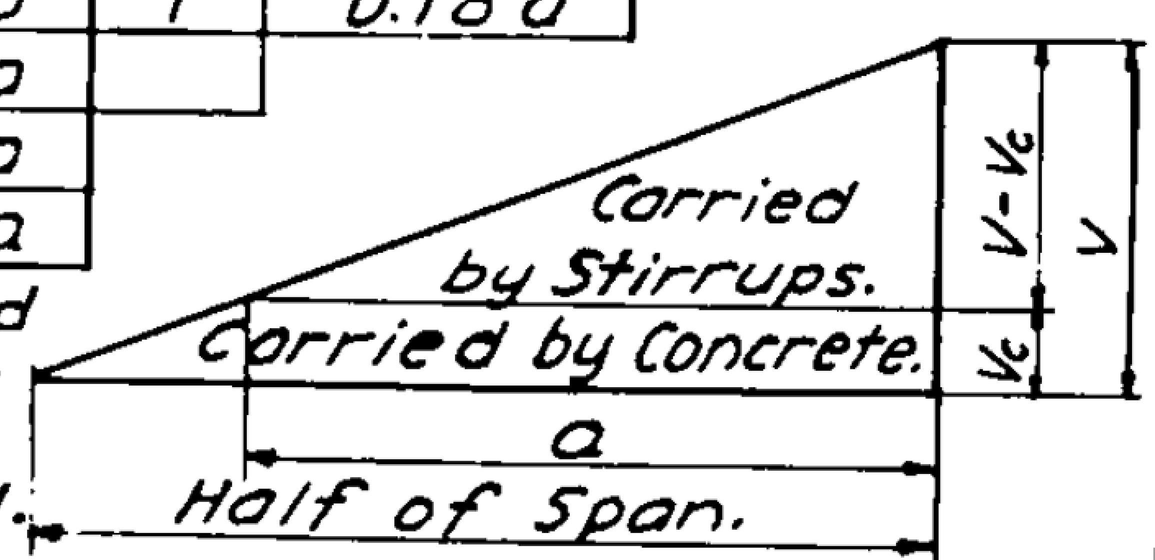
Where: V = Total shear in kips.
V_c = Shear carried by concrete in kips.
a = Distance in inches from end of beam to point where shear = V_c
d = Effective depth of beam in in.

TABLE C - SPACING OF U-SHAPED STIRRUPS FOR UNIFORMLY LOADED BEAMS.*

Spacing, Center To Center Of Stirrups In Terms Of "a".

"N" Number Of Stirrups In One End Of Beam.	Distance From First Stirrup To Face Of Support.	1st Group. Nº	Spacing.	2nd Group. Nº	Spacing.	3rd Group. Nº	Spacing.	4th Group. Nº	Spacing.	5th Group. Nº	Spacing.
20	0.013a	8	0.03a	7	0.04a	2	0.06a	1	0.08a	1	0.11a
19	0.013a	7	0.03a	6	0.04a	3	0.06a	1	0.08a	1	0.12a
18	0.014a	6	0.03a	5	0.04a	4	0.06a	1	0.08a	1	0.12a
17	0.015a	5	0.03a	5	0.04a	4	0.06a	1	0.09a	1	0.13a
16	0.016a	3	0.03a	5	0.04a	5	0.06a	1	0.09a	1	0.13a
15	0.017a	2	0.03a	5	0.04a	4	0.06a	2	0.08a	1	0.14a
14	0.018a	5	0.04a	4	0.05a	2	0.08a	1	0.09a	1	0.14a
13	0.019a	4	0.04a	3	0.05a	3	0.08a	1	0.09a	1	0.14a
12	0.021a	6	0.05a	3	0.07a	1	0.12a	1	0.15a		
11	0.023a	5	0.05a	3	0.08a	1	0.12a	1	0.15a		
10	0.025a	3	0.05a	4	0.08a	1	0.12a	1	0.16a		
9	0.028a	3	0.06a	3	0.09a	1	0.12a	1	0.17a		
8	0.032a	2	0.07a	3	0.09a	1	0.13a	1	0.18a		
7	0.036a	3	0.08a	2	0.13a	1	0.20a				
6	0.04a	3	0.10a	1	0.15a	1	0.22a				
5	0.05a	2	0.12a	1	0.16a	1	0.23a				
4	0.07a	2	0.16a	1	0.26a						
3	0.09a	1	0.21a	1	0.30a						
2	0.13c	1	0.37a								
1	0.29a										

Note: V_c based on $.02f_c'$ or $.03f_c'$, see Page 1-01.



EXAMPLE:

Given: Beam with $b = 12"$; $d = 20"$; span $l = 24'\text{-}0"$ and load = 3000# per lin. ft.
Required: Stirrup spacing using $f_c' = 3{,}000$#/□".
Solution: $V = 3{,}000 \times 12 = 36.0$ kips; $V_c = 12 \times 20 \times \frac{7}{8} \times (0.02f_c') = 12.6$ kips. $V - V_c = 23.4$ kips to be carried by stirrups.
Assuming 3/8" U stirrups - from Table "A" with $f_v = 20{,}000$#/□" and $f_c' = 3{,}000$#/□", 3/8"ϕ U stirrups are satisfactory for $d = 20"$. Solve for a (ins.) $= \frac{23.4}{36.0} \times 12 \times 12 = 93.6"$. Solve for "N" using formula in Table "B":
$N = \frac{23.4 \times 93.6}{7.7 \times 20} = 14.2$. Enter Table "C" at $N = 15$ and find stirrup spacing: 1 @ 1½"; 2 @ 3"; 5 @ 4"; 4 @ 6"; 2 @ 8" and 1 @ 13" - Reduce spacing of 1 @ 13" to 2 @ 10" as the A.C.I. Code requires that the maximum spacing of stirrups when required shall not be greater than 0.5d. Also when maximum unit shear is greater than $0.06f_c'$ this spacing should be reduced to 0.25d.

*Developed from Handbook of Reinforced Concrete Building Design by Arthur R. Lord, reprinted from copyrighted Proceedings - Vol. 24, 1928 - American Concrete Institute.

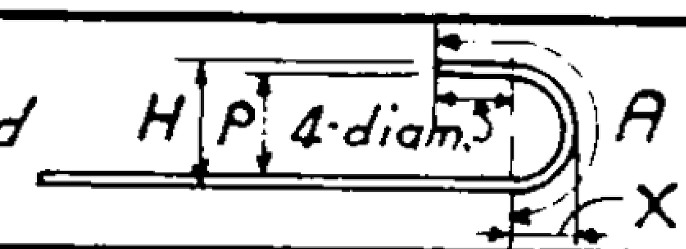
STRUCTURAL - CONCRETE

TABLE A - STANDARD STYLES OF AMERICAN ELECTRICALLY WELDED MESH

SPACING OF WIRES IN INCHES		AMERICAN STEEL & WIRE CO. GAUGE NO.		SECT. AREA PER FT. OF FABRIC (SQ. IN.)	
LONG.	TRANS.	LONG.	TRANS.	LONG.	TRANS.
2	16	1	7	.377	.018
2	16	2	8	.325	.015
2	16	3	8	.280	.015
2	16	4	9	.239	.013
3	16	2	8	.216	.016
2	16	5	10	.202	.011
3	16	3	8	.187	.015
2	16	6	10	.174	.011
3	16	4	9	.159	.013
2	16	7	11	.148	.009
4	16	3	8	.140	.015
3	16	5	10	.135	.011
4	16	4	9	.120	.013
3	16	6	10	.116	.011
4	16	5	10	.101	.011
3	16	7	11	.098	.009
4	16	6	10	.087	.011
3	16	8	12	.082	.007
4	16	7	11	.074	.009
4	12	8	12	.062	.009
4	12	9	12	.052	.009
4	12	10	12	.043	.009
4	12	12	12	.026	.009
6	6	7	7	.049	.049
4	4	4	4	.120	.120
4	4	6	6	.087	.087

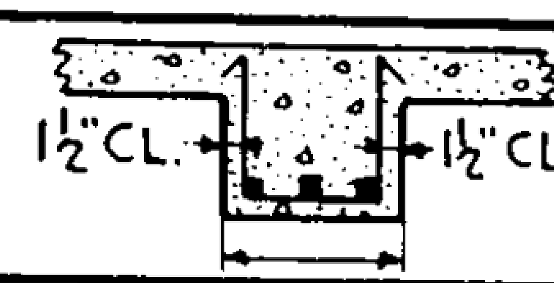
TABLE B - PROPERTIES OF REINFORCING BARS AND HOOK DIMENSIONS

Method of hooking bars as recommended by A. C. I.



SIZE	AREA	PERIM.	WT. #/'	P	H	X	A
1/4" ○	.05	.79	.167	1 1/4"	1 3/4"	7/8"	3 3/8"
3/8" ○	.11	1.18	.376	1 7/8"	2 5/8"	1 3/8"	5"
1/2" ○	.20	1.57	.668	2 1/2"	3 1/2"	1 3/4"	6 3/4"
1/2" □	.25	2.00	.850	2 1/2"	3 1/2"	1 3/4"	6 3/4"
5/8" ○	.31	1.96	1.043	3 1/8"	4 3/8"	2 1/8"	8 3/8"
3/4" ○	.44	2.36	1.502	3 3/4"	5 1/4"	2 5/8"	10"
7/8" ○	.60	2.75	2.044	4 3/8"	6 1/8"	3"	11 3/4"
1" ○	.79	3.14	2.670	5"	7"	3 1/2"	1'-1 3/8"
1" □	1.00	4.00	3.400	5"	7"	3 1/2"	1'-1 3/8"
1 1/8" □	1.27	4.50	4.303	5 5/8"	7 7/8"	3 7/8"	1'-3 1/8"
1 1/4" □	1.56	5.00	5.313	6 1/4"	8 3/4"	4 3/8"	1'-4 3/4"

TABLE C - MINIMUM BEAM WIDTHS IN INCHES *



SIZE OF BAR	NO. OF BARS IN SINGLE LAYER OF REINF.							ADD FOR EACH ADD. BAR
	2	3	4	5	6	7	8	
1/2" φ	6"	7 1/2"	9"					1 1/2"
1/2" □	6 1/2	8	10					1 3/4
5/8" φ	6	8	9 1/2	11	12 1/2			1 5/8
3/4" φ	6 1/2	8 1/2	10 1/2	12	14			1 7/8
7/8" φ	7	9	11 1/2	13 1/2	16	18	20	2 3/16
1" φ	7 1/2	10	12 1/2	15	17 1/2	20	22 1/2	2 1/2"
1" □	8	11	14	17	20	23	26	3
1 1/8" □	8 1/2	12	15	18 1/2	22	25 1/2	28 1/2	3 3/8
1 1/4" □	9	12 1/2	16 1/2	20	24	27	31 1/2	3 3/4

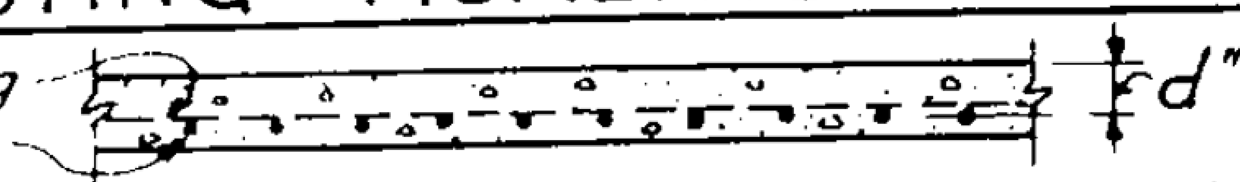
TABLE D - AREA OF STEEL PER FOOT OF WIDTH

BAR SIZE	SPACING OF BARS																
	4"	4 1/2"	5"	5 1/2"	6"	6 1/2"	7"	7 1/2"	8"	8 1/2"	9"	9 1/2"	10"	10 1/2"	11"	11 1/2"	12"
1/4" φ	0.15	0.13	0.12	0.11	0.10	0.09	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05
3/8" φ	0.33	0.29	0.26	0.24	0.22	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11
1/2" φ	0.59	0.52	0.47	0.43	0.39	0.36	0.34	0.31	0.29	0.28	0.26	0.25	0.23	0.22	0.21	0.20	0.20
1/2" □	0.75	0.67	0.60	0.55	0.50	0.46	0.43	0.40	0.37	0.35	0.33	0.32	0.30	0.29	0.27	0.26	0.25
5/8" φ	0.92	0.82	0.74	0.67	0.61	0.57	0.53	0.49	0.46	0.43	0.41	0.39	0.37	0.35	0.33	0.32	0.31
3/4" φ	1.33	1.18	1.06	0.96	0.88	0.82	0.76	0.71	0.66	0.62	0.59	0.56	0.53	0.51	0.48	0.46	0.44
7/8" φ	1.80	1.60	1.44	1.31	1.20	1.11	1.03	0.96	0.90	0.85	0.80	0.76	0.72	0.69	0.66	0.62	0.60
1" φ	2.36	2.09	1.88	1.71	1.57	1.45	1.35	1.26	1.18	1.11	1.05	0.99	0.94	0.90	0.86	0.82	0.78
1" □	3.00	2.67	2.40	2.18	2.00	1.85	1.71	1.60	1.50	1.41	1.33	1.26	1.20	1.14	1.09	1.04	1.00
1 1/8" □	3.80	3.37	3.04	2.76	2.53	2.34	2.17	2.02	1.90	1.79	1.69	1.60	1.52	1.45	1.38	1.32	1.27
1 1/4" □	4.69	4.17	3.75	3.41	3.13	2.89	2.68	2.50	2.34	2.21	2.08	1.97	1.87	1.79	1.70	1.63	1.56

* Where specially anchored bars are used haunch width may be narrowed.

STRUCTURAL - CONCRETE

TABLE A - RESISTING MOMENTS OF CONCRETE SLABS



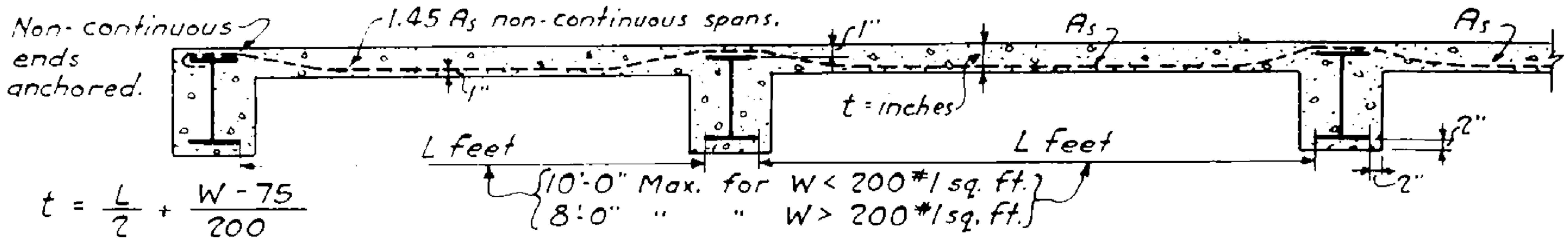
M: Moment of resistance of slabs one foot wide in 1000 foot lbs.
A_s: Tensile steel area in square inches for moment M.

f_s	f'_c	f_c	n	R	p	2		2½		3		3½		4		4½		5		5½		6	
						M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s	M	A_s
20,000	2000	900	15	157.0	.0091	.63	.22	.98	.27	1.41	.33	1.92	.38	2.51	.44	3.2	.49	3.9	.54	4.7	.60	5.7	.65
	2500	1125	12	196.2	.0113	.78	.27	1.23	.34	1.76	.41	2.40	.48	3.14	.54	4.0	.61	4.9	.68	5.9	.75	7.1	.82
	3000	1350	10	235.6	.0136	.94	.33	1.48	.41	2.12	.49	2.89	.57	3.78	.65	4.9	.73	5.9	.82	7.1	.90	8.3	.98
	3750	1700	8	298.0	.0172	1.19	.41	1.86	.52	2.68	.62	3.65	.72	4.77	.82	6.0	.93	7.5	1.03	9.0	1.13	10.7	1.23

(Effective Depth d in inches)

CINDER CONCRETE FLOOR SLABS

NEW YORK CITY BLDG. CODE 1938 - EMPIRICAL FORMULAS.



$$t = \frac{L}{2} + \frac{W-75}{200}$$

$$†A_s = \frac{WL^2}{3C}$$

†Min. A_s = .018(t-1)

t = 4" if L = 8'-0" or less and W = 200 or less.
W = Total uniform load in #/□' (Liveload + Dead load.)
* C = 26,000 for steel fabric of ultimate strength of 71,500#/□".

TABLE B - CROSS SECTIONAL AREA OF WELDED FABRIC PER FT. WIDTH OF SLAB = A_s IN □"

L	3'-0"	4'-0"	5'-0"	6'-0"	7'-0"	8'-0"	9'-0"	10'-0"
W \ t	4" SLAB						5" SLAB	5½" SLAB
80	.054	.054	.054	.054	.054	.066	.083	.103
90	.054	.054	.054	.054	.057	.074	.094	.115
100	.054	.054	.054	.054	.063	.082	.104	.128
110	.054	.054	.054	.054	.069	.090	.114	.141
120	.054	.054	.054	.056	.076	.098	.125	.154
130	.054	.054	.054	.060	.082	.107	.135	.167
140	.054	.054	.054	.065	.088	.115	.146	.180
150	.054	.054	.054	.069	.095	.123	.156	.192
160	.054	.054	.054	.074	.101	.131	.166	.205
170	.054	.054	.054	.079	.107	.140	.177	.218
							5½" SLAB	6" SLAB
180	.054	.054	.058	.083	.113	.148	.187	.230
190	.054	.054	.061	.088	.120	.156	.197	.243
200	.054	.054	.064	.092	.126	.164	.208	.256
W \ t	4½" SLAB					5" SLAB		
210	.063	.063	.067	.097	.132	.173		
220	.063	.063	.071	.102	.138	.181		
230	.063	.063	.074	.106	.145	.189		
240	.063	.063	.077	.111	.151	.197		
250	.063	.063	.080	.115	.157	.206		
260	.063	.063	.083	.120	.163	.214		
270	.063	.063	.087	.125	.170	.222		

MIX
1-Part cement
2-Parts sand
5-Parts cinders
(Clean hard burned anthracite.)

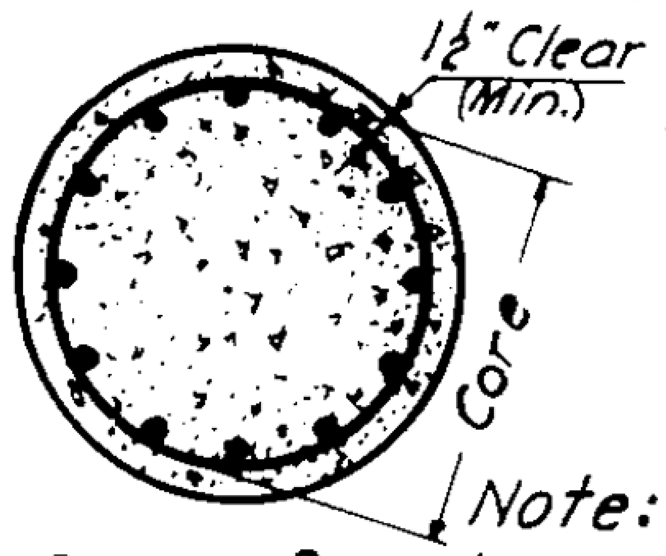
For sizes and spacing of steel mesh see Table A, on Page 1-39.
* C: 29,900 for stone concrete floor slabs (1:2:5 Mix.)

STRUCTURAL - CONCRETE

SPIRALS AND TIES FOR REINFORCED CONCRETE COLUMNS - A.C.I. CODE 1941.

SPIRAL REINFORCEMENT:

Compute the required percentage of spirals (p') by formula, $p' = .45\left(\frac{A_g}{A_c} - 1\right)\frac{f_c'}{f_s'}$. Use Table A to get spiral size and pitch.



A_g = Gross area of column - from Nomographs, pg. 1-42 to 1-45.
A_c = Area of concrete core (out to out of spirals) - see bottom of Tab. A.
f_c' = Ultimate strength of concrete at 28 days.
f_s' = 40,000 #/□" for hot rolled intermediate grade steel; 50,000 #/□" for hard grade steel; and 60,000 #/□" for cold drawn wire.

Note:- Minimum diameter of spirals to be ¼"ϕ for rolled bars or No. 4 W&M gage for drawn wire. The center to center spacing of spirals shall not exceed one-sixth of the core diameter. Clear spacing between spirals shall not exceed 3" nor be less than 1⅜" or 1½ times the maximum size of aggregate used.

TABLE A - PERCENTAGE OF SPIRALS.

SIZE OF ROD	PITCH	11	13	15	17	19	21	23	25	27	29	31	33
¼"ϕ	1¾"	1.04	.88	.76	.67	.60	.54	.50	.46	.42	.39	.37	.35
	2"	-	.77	.67	.59	.53	.48	.43	.40	.37	.34	.32	.30
	2½"	-	-	.53	.47	.42	.38	.35	.32	.30	.28	.26	.24
	3"	-	-	-	-	.35	.32	.29	.27	.25	-	-	-
5/16"ϕ	1¾"	1.60	1.36	1.17	1.04	.93	.84	.77	.70	.65	.60	.56	.53
	2"	-	1.18	1.02	.90	.80	.73	.67	.61	.57	.53	.49	.46
	2½"	-	-	.82	.72	.64	.58	.53	.49	.45	.42	.40	.37
	3"	-	-	-	-	.54	.49	.44	.41	.38	.35	.33	.31
⅜"ϕ	1¾"	2.29	1.93	1.68	1.48	1.32	1.20	1.09	1.01	.93	.87	.81	.76
	2"	-	1.69	1.47	1.29	1.16	1.05	.96	.88	.82	.76	.71	.67
	2½"	-	-	1.17	1.03	.93	.84	.76	.70	.65	.61	.57	.53
	3"	-	-	-	-	.77	.70	.64	.58	.54	.50	.47	.44
CORE AREA □"		95	133	177	227	284	346	415	491	573	661	755	855
I_c - IN.⁴		718	1,402	2,485	4,100	6,397	9,547	13,737	19,125	26,087	34,719	45,333	58,214

SIZE OF ROD	PITCH	11	13	15	17	19	21	23	25	27	29	31	33
7/16"ϕ	2"	-	2.31	2.00	1.77	1.58	1.43	1.31	1.20	1.11	1.03	.97	.91
	2¼"	-	-	1.79	1.58	1.41	1.28	1.16	1.07	.99	.92	.87	.81
	2½"	-	-	1.60	1.41	1.26	1.14	1.04	.96	.89	.83	.77	.73
	3"	-	-	-	-	1.05	.95	.87	.80	.74	.69	.64	.60
½"ϕ	2"	-	-	2.67	2.35	2.11	1.90	1.74	1.60	1.48	1.38	1.29	1.21
	2¼"	-	-	2.37	2.09	1.87	1.69	1.55	1.42	1.31	1.22	1.15	1.08
	2½"	-	-	2.13	1.88	1.68	1.52	1.39	1.28	1.19	1.10	1.05	.97
	3"	-	-	-	-	1.40	1.27	1.16	1.07	.99	.92	.86	.81
⅝"ϕ	2"	-	-	-	3.60	3.22	2.92	2.67	2.45	2.27	2.12	1.98	1.86
	2¼"	-	-	-	3.21	2.87	2.60	2.37	2.18	2.02	1.88	1.76	1.65
	2½"	-	-	-	2.90	2.62	2.36	2.16	1.99	1.84	1.69	1.58	1.50
	3"	-	-	-	-	2.17	1.97	1.80	1.65	1.53	1.42	1.33	1.25

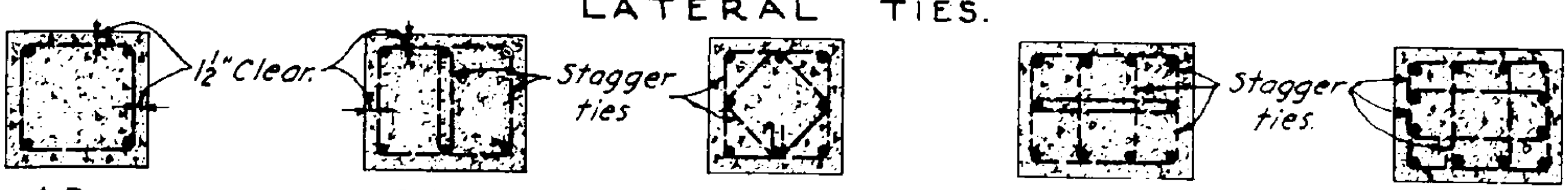
TABLE B - EQUIVALENT CONCRETE MOMENT OF INERTIA FOR 1% OF VERTICAL STEEL $(n-1)I_s$.

CORE DIA	11	13	15	17	19	21	23	25	27	29	31	33
f_c'=2,000	218	426	754	1,166	1,922	2,856	4,098	5,703	7,733	10,230	13,770	17,150
f_c'=2,500	172	335	593	916	1,510	2,244	3,220	4,481	6,076	8,050	10,500	13,470
f_c'=3,000	140	274	485	750	1,236	1,836	2,635	3,666	4,971	6,590	8,590	11,030
f_c'=3,750	109	213	377	583	961	1,428	2,049	2,852	3,867	5,125	6,880	8,575

TABLE C - MAX. NUMBER OF BARS IN ONE CORE RING.

BAR SIZE \ CORE DIA.	11	13	15	17	19	21	23	25	27	29	31	33
⅝"ϕ	10	13	15	17	19	22	24	26	29	31	33	35
¾"ϕ	9	11	13	16	18	20	22	24	26	28	30	32
⅞"ϕ	8	10	12	14	16	18	20	22	24	26	28	30
1"ϕ	8	9	11	13	15	17	18	20	22	24	26	28
1"□	7	8	10	11	13	14	16	18	19	21	22	24
1⅛"□	6	7	9	10	11	13	14	16	17	18	19	20
1¼"□	-	6	8	9	10	11	13	14	15	16	17	18

LATERAL TIES.



4 BARS | 6 BARS | 8 BARS | 10 BARS | 12 BARS

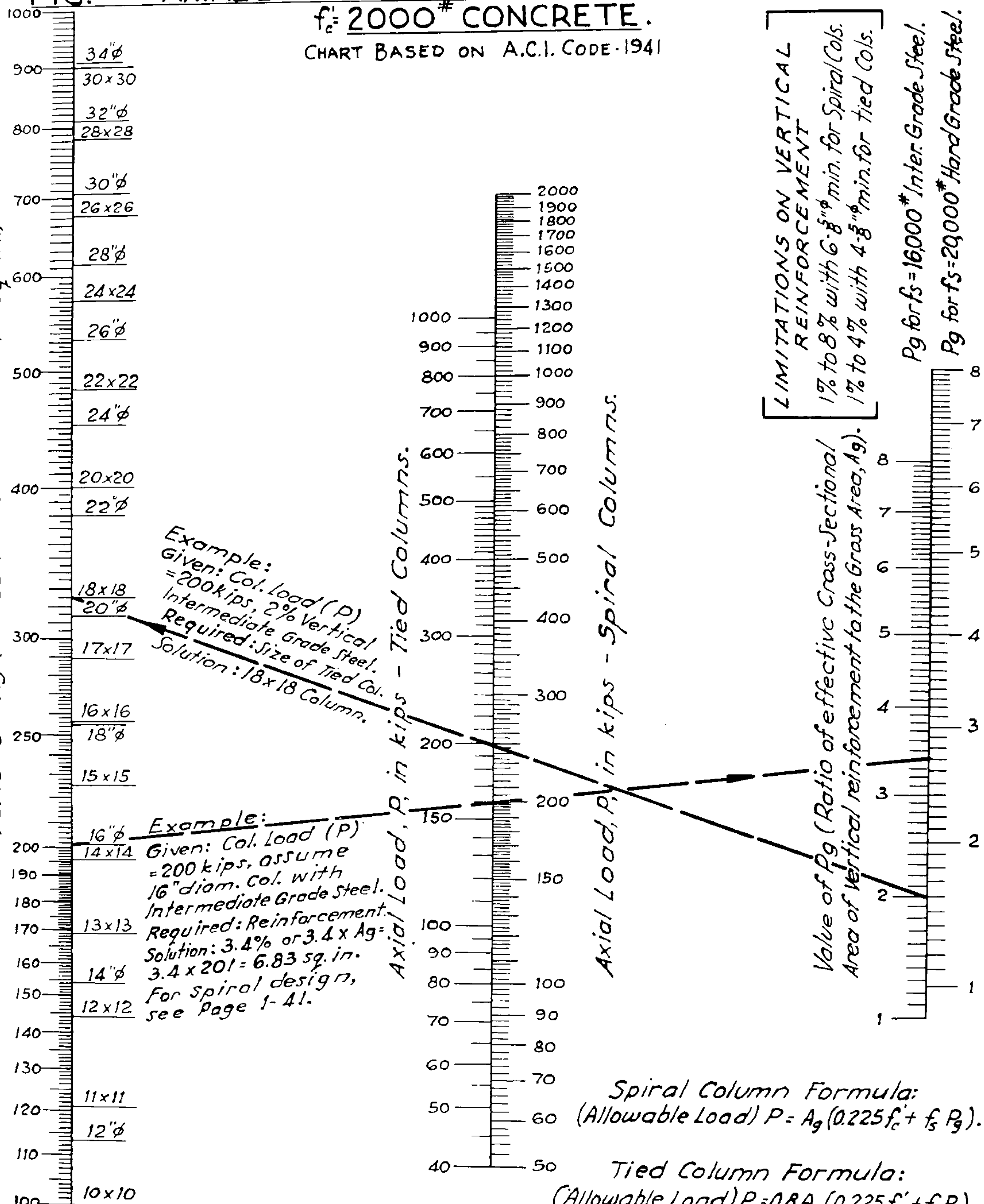
NOTE:- Lateral ties shall be a minimum of ¼"ϕ rods spaced not over 16 vertical bar diameters, 48 tie diameters, or the least dimension of the column. When there are more than 4 vertical bars, additional ties shall be provided so that every longitudinal bar is held firmly in its designed position and has lateral support equivalent to that provided by a 90° corner of a tie (See sketches above).

STRUCTURAL - CONCRETE

FIG. A - AXIAL LOADS IN KIPS FOR TIED & SPIRAL COLUMNS.

f'_c = 2000# CONCRETE.

CHART BASED ON A.C.I. CODE-1941



Spiral Column Formula:
(Allowable Load) $P = A_g(0.225 f'_c + f_s P_g)$.

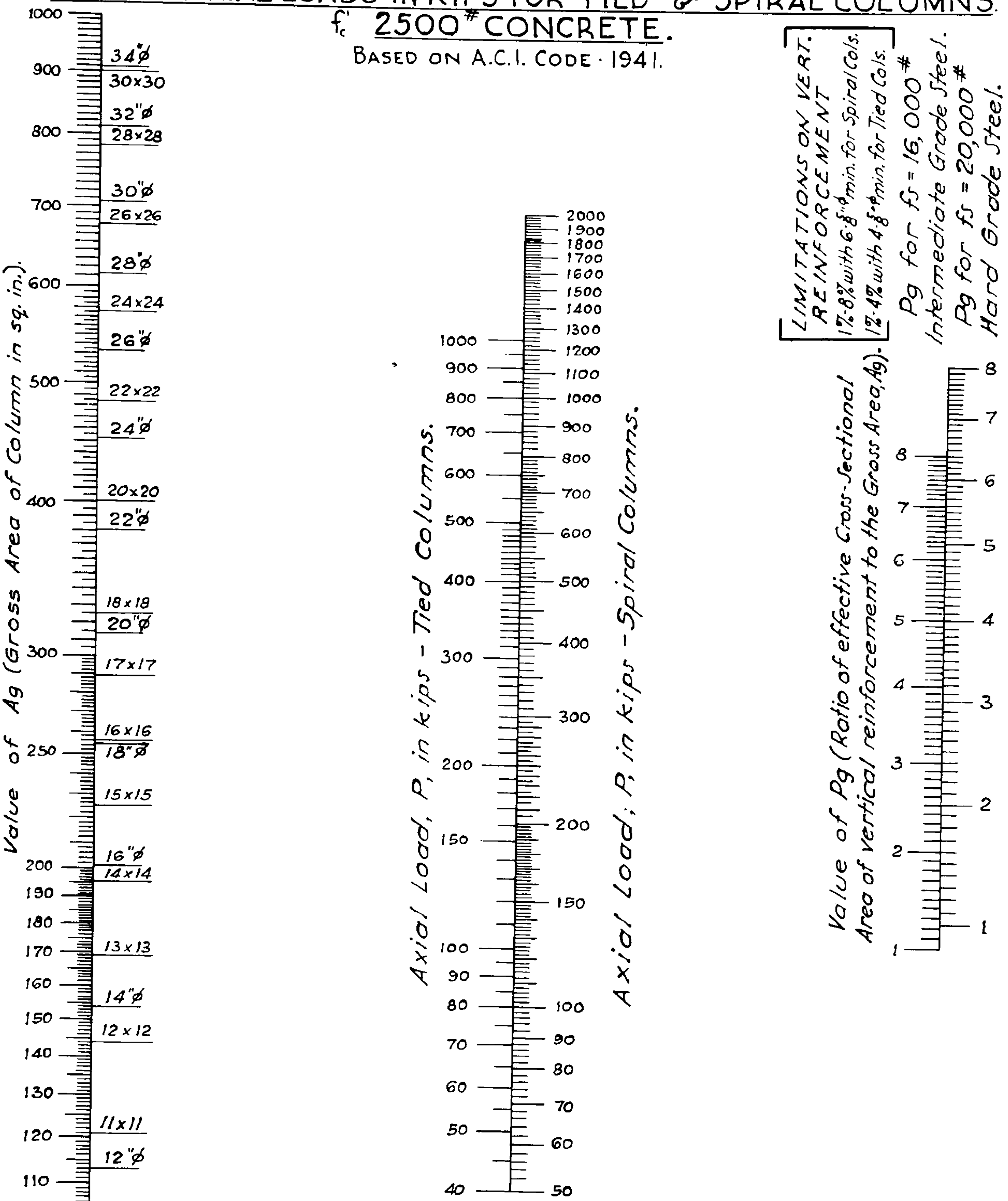
Tied Column Formula:
(Allowable Load) $P = 0.8 A_g(0.225 f'_c + f_s P_g)$.

STRUCTURAL — CONCRETE

FIG. A — AXIAL LOADS IN KIPS FOR TIED & SPIRAL COLUMNS.

f'_c 2500# CONCRETE.

BASED ON A.C.I. CODE · 1941.



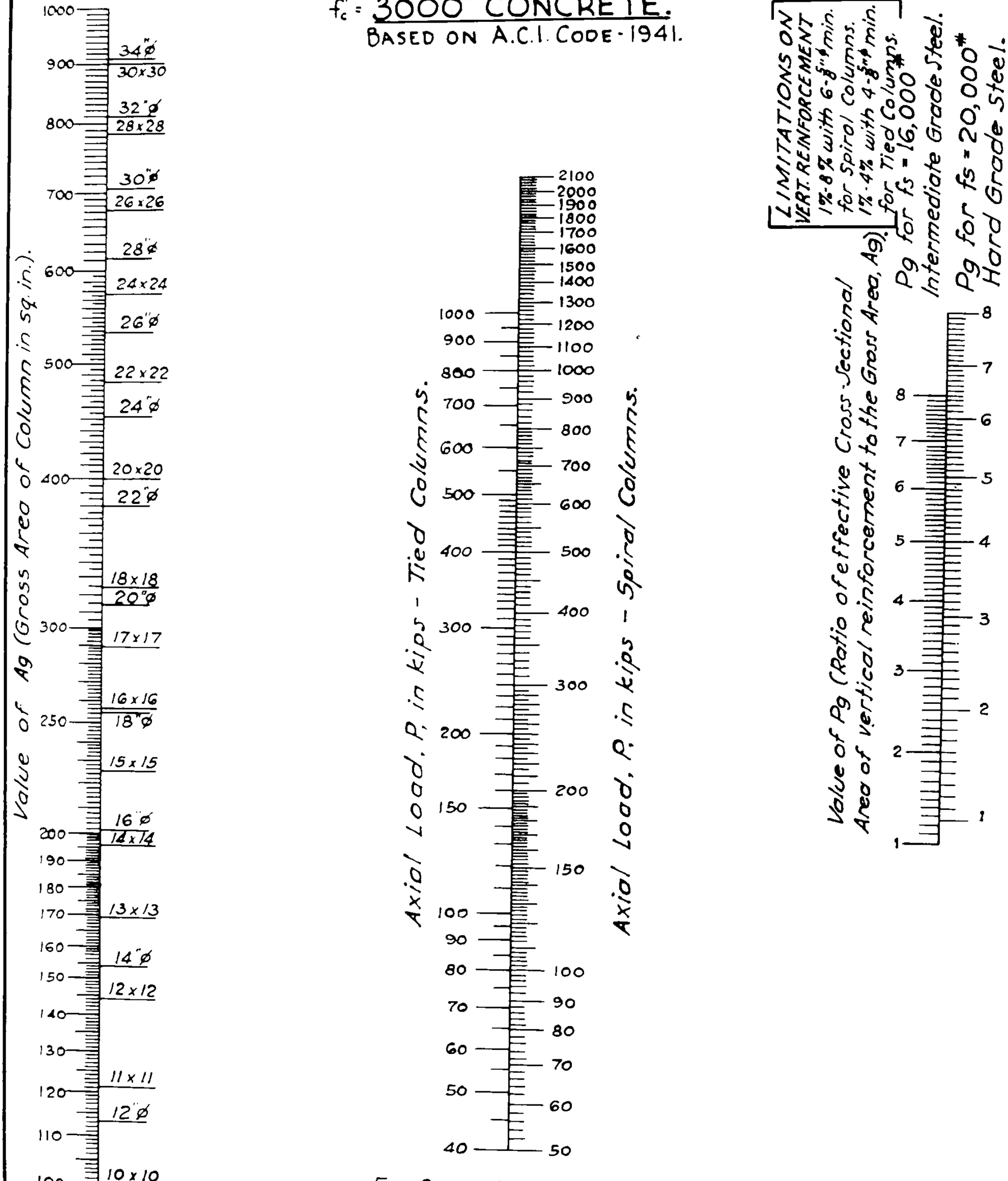
For formulas and example see page 1-42.

STRUCTURAL — CONCRETE

FIG. A — AXIAL LOADS IN KIPS FOR TIED & SPIRAL COLUMNS.

f'_c = 3000# CONCRETE.

BASED ON A.C.I. CODE-1941.



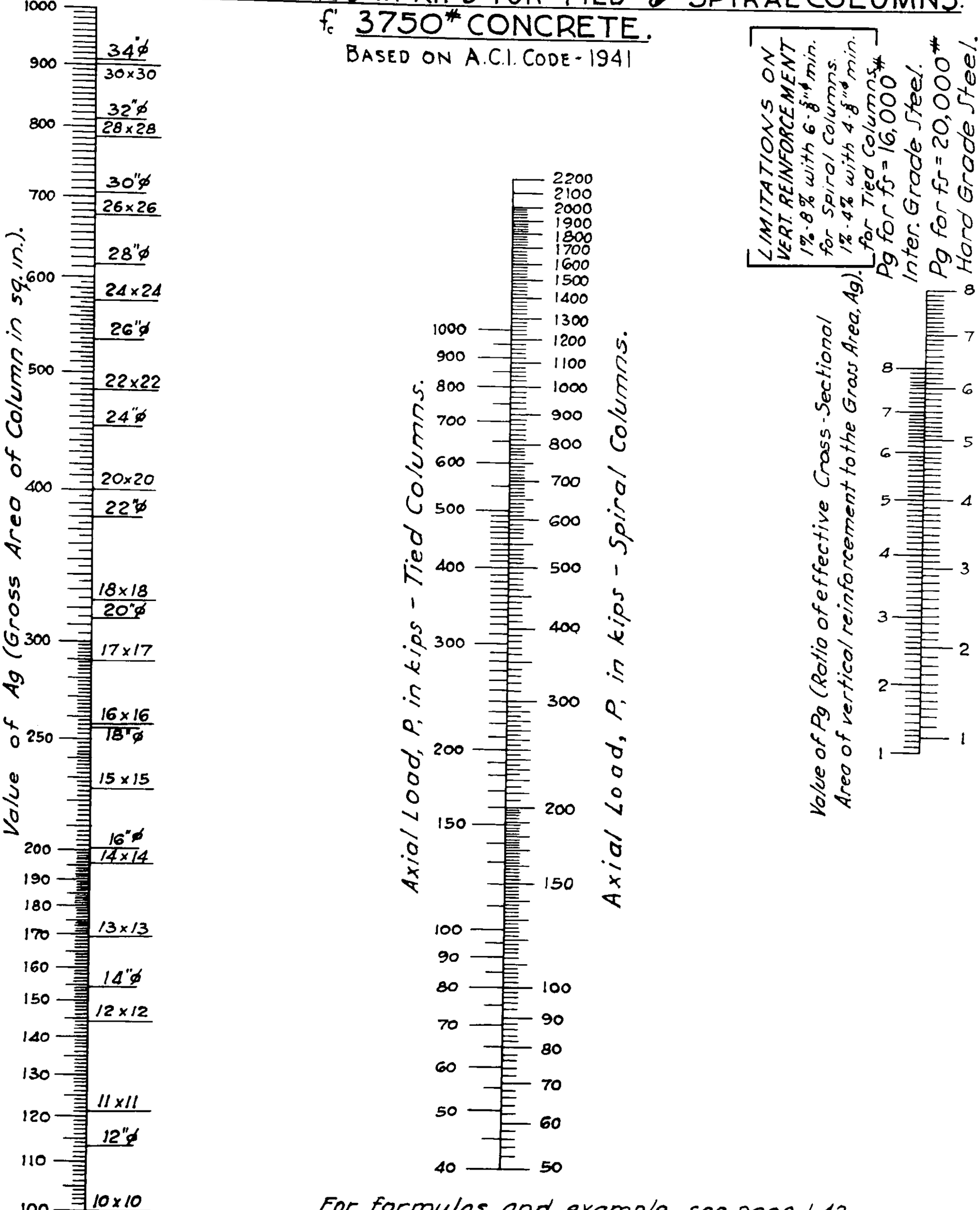
For formulas and example see page 1-42.

STRUCTURAL — CONCRETE

FIG. A - AXIAL LOADS IN KIPS FOR TIED & SPIRAL COLUMNS.

f'_c 3750# CONCRETE.

BASED ON A.C.I. CODE - 1941



For formulas and example see page 1-42.

STRUCTURAL - CONCRETE

EQUIVALENT CONCENTRIC LOADS FOR RECTANGULAR COLUMNS SUBJECT TO BENDING.

(VERTICAL REINFORCEMENT & TIES.)

Case I: Moment About One Axis.

Equivalent Concentric Load = CP

See example page 1-47.

Notation:

C = Bending factor from diagram.
P = Vertical load in kips.
M = Bending moment in foot-kips.
M_x = Bending moment about 'X' axis.
M_y = Bending moment about 'Y' axis.
P_y = Equivalent concentric load due to M_y and P.
P_{xy} = Equivalent concentric load due to M_x; M_y and P.
$\propto$ = Varies with.

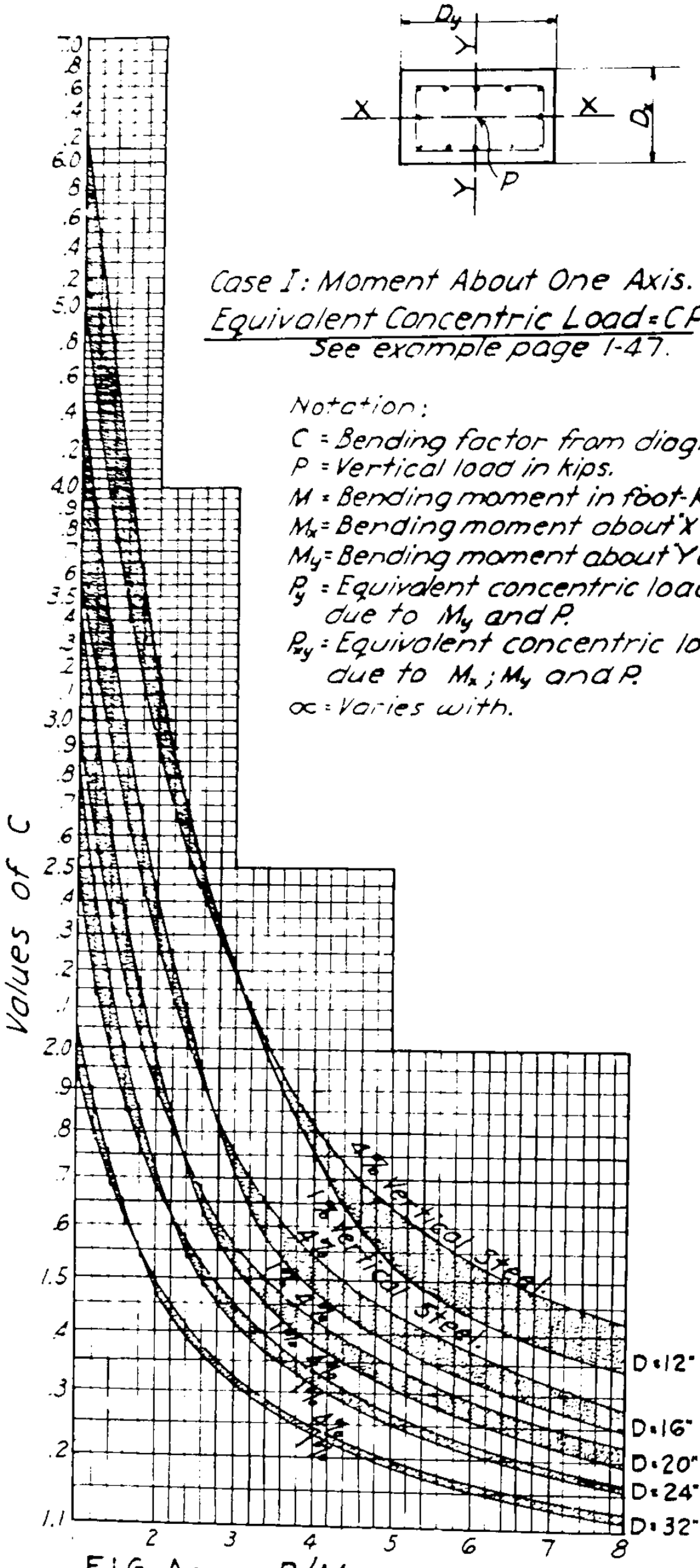


FIG. A-

Case II: Moment About Two Axes.

Assume a size of column and percentage of reinforcement. Compute partial equivalent load due to P and M_y with depth = D_y by:

$P_y = P C_y$ where $C_y \propto P/M_y$.

Compute total equivalent load due to P, M_x and M_y with depth = D_x by:

$P_{xy} = P_y C_x$ where $C_x \propto P_y/M_x$

Design column by method given in Fig. A, page 1-42. Recheck for equivalent load if necessary.

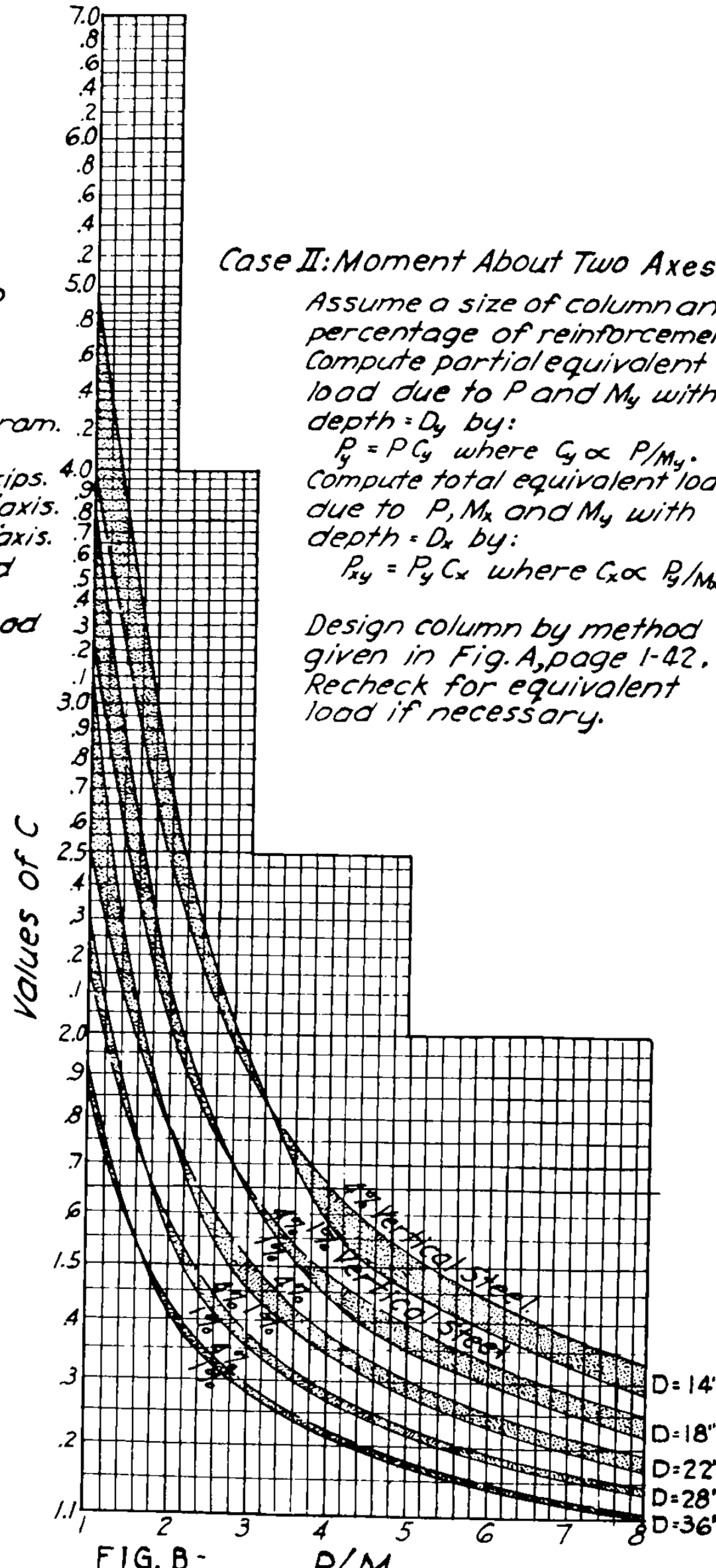
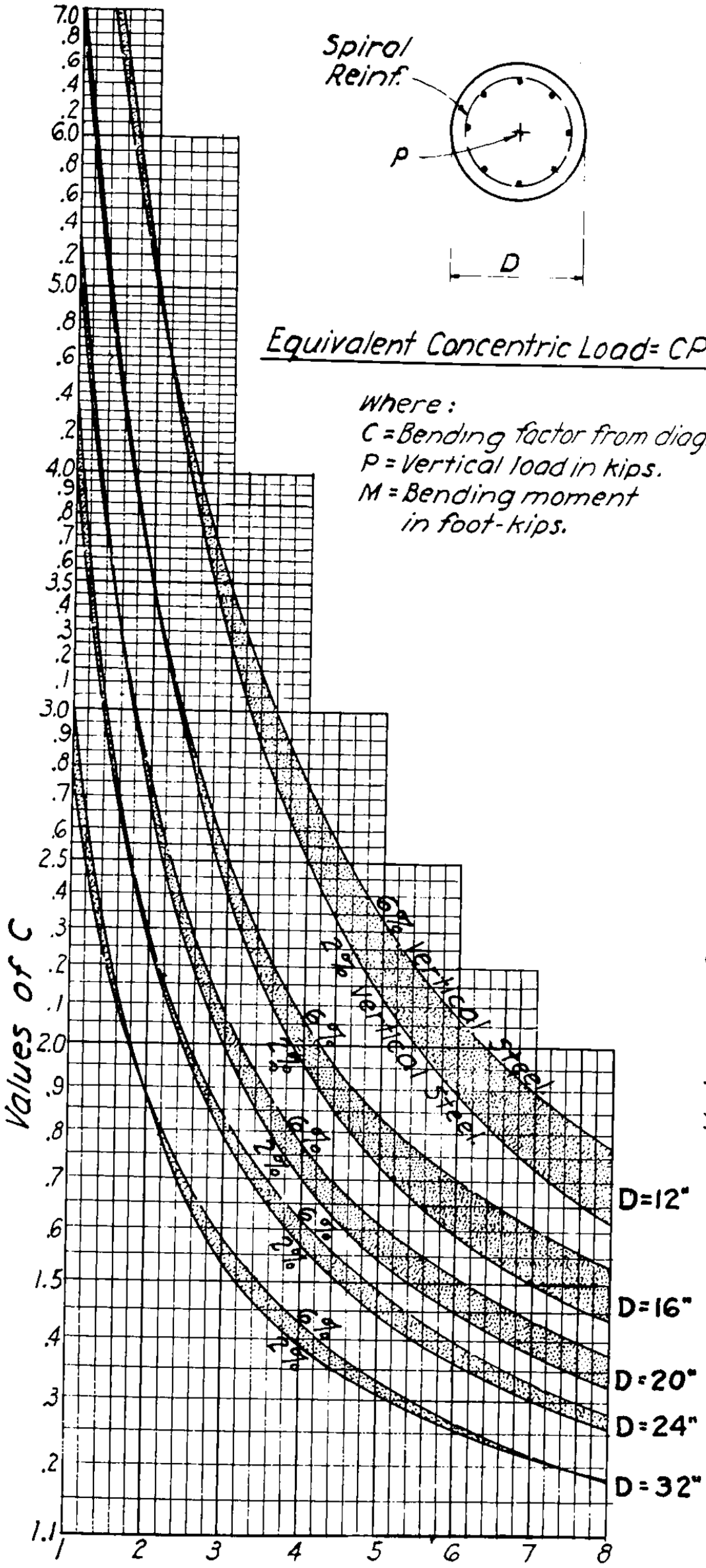


FIG. B-

Note: Values of C computed for 3000# concrete - Variation for 2000# to 3750# concrete neglected as slight. Charts based on the symmetrical placing of reinforcement in the column faces parallel to the neutral axis. Computed for no tension in concrete (cracked section) according to A.C.I. Code 1941.

STRUCTURAL - CONCRETE

EQUIVALENT CONCENTRIC LOADS FOR CIRCULAR & OCTAGONAL COLUMNS SUBJECT TO BENDING.
(WITH VERTICAL & SPIRAL REINFORCEMENT)



Equivalent Concentric Load = CP

Where:
C = Bending factor from diagram.
P = Vertical load in kips.
M = Bending moment in foot-kips.

FIG. A - P/M

EXAMPLE:
Given: A concentric load of 300 kips and a bending moment, M = 70 Ft.-kips.

Required: Diameter of col. and % of reinforcement.

Solution: P/M = 4.3
To determine equivalent concentric load -
Assume column Dia. = 22 In.
Assume 4% Reinf. steel.
(Cut and try)
Enter Fig. B at P/M = 4.3
Find intersection at curve for D = 22" and 4% Vert. steel.
Read C = 1.6
The equivalent concentric load = 1.6 x 300 = 480 kips.
Design column by method given in Fig. A page 1-42.
Recheck for equivalent concentric load if necessary.

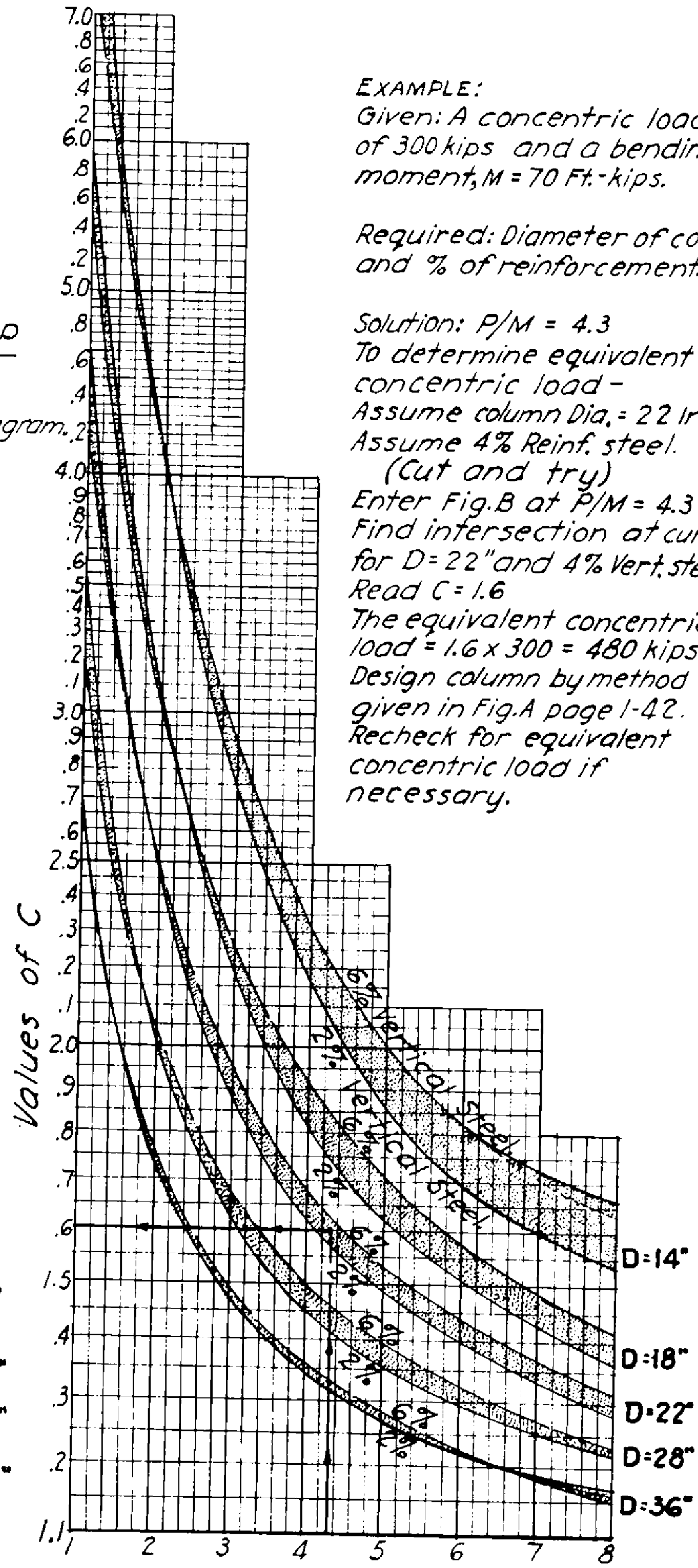


FIG. B - P/M

Note: Values of C computed for 3000# concrete - variation for 2,000# to 3750# concrete neglected as slight. Computed for no tension in concrete (cracked section) according to A.C.I. Code - 1941.

STRUCTURAL

BETHLEHEM AND CARNEGIE STRUCTURAL SECTIONS

D	Wt	S	t	V	R	G	d	b	r'	Wh
36 WF	300	1105.1	.94	451	143	22.7	36¾	16⅝	3.73	
	280	1031.2	.88	420	132	21.2	36½	16⅝	3.70	790C
	260	951.1	.84	398	123	20.3	36¼	16½	3.65	950S
	245	892.5	.80	376	115	19.2	36	16½	3.62	
	230	835.5	.76	357	108	18.4	35⅞	16½	3.59	
	194	663.6	.77	365	104	18.5	36½	12⅛	2.49	
	182	621.2	.72	342	97	17.4	36⅜	12⅛	2.47	590C
	170	579.1	.68	320	89	16.3	36⅛	12	2.45	710S
	160	541.0	.65	306	84	15.7	36	12	2.42	
	150	502.9	.62	291	80	15.0	35⅞	12	2.38	
33 WF	240	811.1	.83	362	118	19.9	33½	15⅞	3.52	700C
	220	740.6	.77	335	108	18.6	33¼	15¾	3.48	840S
	200	669.6	.71	307	98	17.2	33	15¾	3.43	
	152	486.4	.63	277	82	15.2	33½	11⅝	2.39	
	141	446.8	.60	262	76	14.5	33¼	11½	2.35	510C
	130	404.8	.58	250	72	13.9	33⅛	11½	2.29	620S
30 WF	210	649.9	.77	306	108	18.6	30⅜	15⅛	3.38	
	190	586.1	.71	278	97	17.0	30⅛	15	3.34	600C
	172	528.2	.65	254	87	15.7	29⅞	15	3.30	730S
	132	379.7	.61	247	77	14.8	30¼	10½	2.18	
	124	354.6	.58	229	72	14.0	30⅛	10½	2.16	430C
	116	327.9	.56	220	69	13.5	30	10½	2.12	530S
	108	299.2	.54	212	66	13.2	29⅞	10½	2.06	
27 WF	177	492.8	.73	257	98	17.4	27¼	14⅛	3.16	510C
	160	444.5	.66	232	88	15.8	27⅛	14	3.12	620S
	145	402.9	.60	210	78	14.4	26⅞	14	3.09	
	114	299.2	.57	202	70	13.7	27¼	10⅛	2.11	
	102	266.3	.52	182	63	12.4	27⅛	10	2.08	370C
	94	242.8	.49	171	59	11.8	26⅞	10	2.04	460S

D	Wt	S	t	V	R	G	d	b	r'	Wh
24 WF	160	413.5	.66	211	87	15.7	24¾	14⅛	3.23	470C
	145	372.5	.61	194	79	14.6	24½	14	3.19	570S
	130	330.7	.56	178	71	13.6	24¼	14	3.13	
	120	299.1	.56	176	69	13.3	24¼	12⅛	2.68	
	110	274.4	.51	160	63	12.2	24⅛	12	2.66	390C
	100	248.9	.47	146	57	11.2	24	12	2.63	470S
	94	220.9	.52	163	61	12.4	24¼	9	1.92	
	84	196.3	.47	147	55	11.3	24⅛	9	1.89	310C
	76	175.4	.44	137	50	10.6	23⅞	9	1.85	380S
21 WF	142	317.2	.66	184	85	15.8	21½	13⅛	3.04	390C
	127	284.1	.59	162	74	14.1	21¼	13	3.01	470S
	112	249.6	.53	144	65	12.7	21	13	2.96	
	96	197.6	.57	158	70	13.8	21⅛	9	1.97	290C
	82	168.0	.50	135	59	12.0	20⅞	9	1.93	350S
	73	150.7	.45	126	53	10.9	21¼	8¼	1.76	
	68	139.9	.43	118	49	10.3	21⅛	8¼	1.74	250C
	62	126.4	.40	109	45	9.6	21	8¼	1.71	310S
18 WF	114	220.1	.59	143	74	14.3	18⅜	11¾	2.76	330C
	105	202.2	.55	132	68	13.3	18¼	11¾	2.73	390S
	96	184.4	.51	121	62	12.3	18⅛	11¾	2.71	
	85	156.1	.53	125	63	12.6	18⅜	8⅞	2.00	
	77	141.7	.47	112	56	11.4	18⅛	8¾	1.98	240C
	70	128.2	.44	103	51	10.5	18	8¾	1.95	290S
	64	117.0	.40	94	46	9.7	17⅞	8¾	1.93	
	60	107.8	.42	99	47	10.0	18¼	7½	1.63	200C
	55	98.2	.39	92	43	9.4	18⅛	7½	1.61	240S
	50	89.0	.36	84	39	8.6	18	7½	1.59	
16 WF	96	166.1	.53	114	66	12.8	16⅜	11½	2.71	300C
	88	151.3	.50	106	61	12.1	16⅛	11½	2.67	360S
	78	127.8	.53	112	64	12.7	16⅜	8⅝	1.95	
	71	115.9	.49	102	57	11.7	16⅛	8½	1.93	210C
	64	104.2	.44	92	51	10.6	16	8½	1.91	260S
	58	94.1	.41	84	46	9.8	15⅞	8½	1.88	
	50	80.7	.38	80	42	9.1	16¼	7⅛	1.54	
	45	72.4	.35	73	38	8.3	16⅛	7	1.52	170C
	40	64.4	.31	64	33	7.4	16	7	1.50	210S
	36	56.3	.30	62	32	7.2	15⅞	7	1.45	

D	Wt	S	t	V	R	G	d	b	r'	Wh
14 WF	426	707.4	1.87	455	321	45.0	18¾	16¾	4.34	670C
	398	656.9	1.77	422	295	42.5	18¼	16⅝	4.31	760S
	370	608.1	1.65	386	268	39.7	18	16½	4.27	
	342	559.4	1.54	353	244	37.1	17½	16⅜	4.24	590C
	314	511.9	1.41	316	217	34.0	17⅛	16¼	4.20	670S
	287	465.5	1.31	286	194	31.4	16¾	16⅛	4.17	510C
	264	427.4	1.20	258	175	28.9	16½	16	4.14	590S
14 WF	246	397.4	1.12	238	160	27.0	16¼	16	4.12	
	237	382.2	1.09	228	154	26.2	16⅛	15⅞	4.11	
	228	367.8	1.04	217	146	25.1	16	15⅞	4.10	460C
	219	352.6	1.00	207	139	24.1	15⅞	15⅞	4.08	530S
	211	339.2	.98	201	134	23.5	15¾	15¾	4.07	
	202	324.9	.93	189	125	22.3	15⅝	15¾	4.06	
	193	310.0	.89	179	119	21.4	15½	15¾	4.05	
	184	295.8	.84	168	111	20.2	15⅜	15⅝	4.04	
	176	281.9	.82	163	107	19.7	15¼	15⅝	4.02	400C
	167	267.3	.78	154	100	18.7	15⅛	15⅝	4.01	460S
	158	253.4	.73	142	93	17.5	15	15½	4.00	
	150	240.2	.69	134	88	16.7	14⅞	15½	3.99	
	142	226.7	.68	130	85	16.3	14¾	15½	3.97	
	320	492.8	1.89	413	281	45.4	16¾	16¾	4.17	570C 650S
14 WF	136	216.0	.66	127	82	15.8	14¾	14¾	3.77	
	127	202.0	.61	116	75	14.6	14⅝	14¾	3.76	
	119	189.4	.57	107	69	13.7	14½	14⅝	3.75	310C
	111	176.3	.54	101	65	13.0	14⅜	14⅝	3.73	370S
	103	163.6	.49	92	59	11.9	14¼	14⅝	3.72	
	95	150.6	.46	85	55	11.2	14⅛	14½	3.71	
	87	138.1	.42	76	49	10.1	14	14½	3.70	
14 WF	84	130.9	.45	83	53	10.8	14⅛	12	3.02	
	78	121.1	.43	78	49	10.3	14	12	3.00	
	74	112.3	.45	83	53	10.8	14¼	10⅛	2.48	220C
	68	103.0	.42	76	48	10.0	14	10	2.46	260S
	61	92.2	.38	68	43	9.1	13⅞	10	2.45	
	53	77.8	.37	67	42	8.9	14	8	1.92	
	48	70.2	.34	61	38	8.1	13¾	8	1.91	160C
	43	62.7	.31	55	34	7.4	13⅝	8	1.89	200S
	38	54.6	.31	58	34	7.5	14⅛	6¾	1.49	
	34	48.5	.29	52	31	6.9	14	6¾	1.46	
	30	41.8	.27	49	28	6.5	13⅞	6¾	1.41	

D	Wt	S	t	V	R	G	d	b	r'	Wh
12 WF	190	263.2	1.06	198	148	25.4	14⅜	12⅝	3.25	
	161	222.2	.90	163	121	21.7	13⅞	12½	3.20	340C
	133	182.5	.75	131	96	18.1	13⅜	12⅜	3.16	390S
	120	163.4	.71	121	88	17.0	13⅛	12⅜	3.13	
	106	144.5	.62	104	75	14.9	12⅞	12¼	3.11	
	99	134.7	.58	96	70	13.9	12¾	12¼	3.09	
	92	125.0	.54	89	65	13.1	12⅝	12⅛	3.08	
	85	115.7	.49	80	58	11.9	12½	12⅛	3.07	230C
	79	107.1	.47	76	54	11.3	12⅜	12⅛	3.05	280S
	72	97.5	.43	69	49	10.3	12¼	12	3.04	
	65	88.0	.39	61	44	9.4	12⅛	12	3.02	
12 WF	58	78.1	.36	57	41	8.6	12¼	10	2.51	180C
	53	70.7	.34	54	39	8.3	12	10	2.48	220S
	50	64.7	.37	59	42	8.9	12¼	8⅛	1.96	
	45	58.2	.34	53	38	8.1	12	8	1.94	150C
	40	51.9	.29	46	33	7.1	12	8	1.94	180S
	36	45.9	.30	49	33	7.3	12¼	6⅝	1.50	
	31	39.4	.27	42	28	6.4	12⅛	6½	1.47	120C
	27	34.1	.24	37	25	5.8	12	6½	1.44	150S
	22	25.3	.26	42	27	6.2	12¼	4	.84	
	19	21.4	.24	38	24	5.8	12⅛	4	.81	
	16.5	17.5	.23	36	23	5.5	12	4	.76	80C
	14	14.8	.20	31	20	4.8	11⅞	4	.74	100S
10 WF	112	126.3	.75	112	95	18.1	11⅜	10⅜	2.67	230C
	100	112.4	.68	99	85	16.5	11⅛	10⅜	2.65	260S
	89	99.7	.61	87	74	14.8	10⅞	10¼	2.63	
	77	86.1	.53	74	62	12.8	10⅝	10¼	2.60	
	72	80.1	.51	70	59	12.2	10½	10⅛	2.59	
	66	73.7	.46	62	52	11.0	10⅜	10⅛	2.58	160C
	60	67.1	.41	55	47	10.0	10¼	10⅛	2.57	190S
	54	60.4	.37	48	41	8.8	10⅛	10	2.56	
	49	54.6	.34	44	37	8.2	10	10	2.54	
10 WF	45	49.1	.35	46	39	8.4	10⅛	8	2.00	120C
	39	42.2	.32	41	35	7.6	10	8	1.98	140S
	33	35.0	.29	37	31	7.0	9¾	8	1.94	
	29	30.8	.29	38	30	6.9	10¼	5¾	1.34	
	25	26.4	.25	33	26	6.0	10⅛	5¾	1.31	90C
	21	21.5	.24	31	24	5.8	9⅞	5¾	1.25	110S
	19	18.8	.25	33	25	6.0	10¼	4	.86	
	17	16.2	.24	32	24	5.8	10⅛	4	.83	70C
	15	13.8	.23	30	22	5.5	10	4	.80	80S
	11.5	10.5	.18	23	17	4.3	9⅞	4	.77	

ALLOWABLE WORKING STRESSES FOR COLUMNS (IN KIPS) VARIOUS VALUES OF l/r (A.I.S.C.)

l/r	f	l/r	f	l/r	f	l/r	f	l/r	f	l/r	f	l/r	f
1	73	60	15.3	71	14.6	82	13.7	93	12.8	104	11.8	115	10.6
10	70	61	15.2	72	14.5	83	13.7	94	12.7	105	11.7	116	10.5
15	69	62	15.1	73	14.4	84	13.6	95	12.6	106	11.6	117	10.4
20	68	63	15.1	74	14.3	85	13.5	96	12.5	107	11.5	118	10.3
25	67	64	15.0	75	14.3	86	13.4	97	12.4	108	11.3	119	10.1
30	66	65	15.0	76	14.2	87	13.3	98	12.3	109	11.2	120	10.0
35	64	66	14.9	77	14.1	88	13.2	99	12.3	110	11.1	121	9.9
40	62	67	14.8	78	14.1	89	13.2	100	12.2	111	11.0	122	9.9
45	60	68	14.8	79	14.0	90	13.1	101	12.1	112	10.9	123	9.8
50	58	69	14.7	80	13.9	91	13.0	102	12.0	113	10.8	124	9.7
55	55	70	14.6	81	13.8	92	12.9	103	11.9	114	10.7	125	9.6

ALLOWABLE FIBER STRESS AND PROPORTION OF SAFE S FOR BEAMS UNSUPPORTED LATERALLY (A.I.S.C.)

l/b	f	S'/S	l/b	f	S'/S
15	20000	1.000	26	16360	.818
16	19700	.985	27	16010	.801
17	19390	.969	28	15670	.784
18	19070	.953	29	15340	.767
19	18740	.937	30	15000	.750
20	18410	.920	31	14670	.733
21	18070	.904	32	14340	.717
22	17730	.887	34	13700	.685
23	17390	.869	36	13080	.654
24	17050	.852	38	12490	.624
25	16700	.835	40	11910	.596

DEFLECTION COEFFICIENT - UNIFORM LOADS 20,000 #/□"

$$\text{DEFL. INCHES} = \frac{\text{DEFL. COE.}}{d} = \frac{.02069\,L^2}{d}$$

L	DEFL. COE.	L	DEF. COE.	L	DEF. COE.	L	DEF. COE.	L	DEF. COE.
21	9.124	31	19.883	41	34.780	51	53.815	62	79.532
22	10.014	32	21.187	42	36.497	52	55.946	64	84.746
23	10.945	33	22.531	43	38.256	53	58.118	66	90.126
24	11.917	34	23.918	44	40.056	54	60.332	68	95.671
25	12.931	35	25.345	45	41.897	55	62.587	70	101.381
26	13.986	36	26.814	46	43.780	56	64.884	72	107.257
27	15.083	37	28.325	47	45.704	57	67.222	74	113.298
28	16.221	38	29.876	48	47.670	58	69.601	76	119.509
29	17.400	39	31.469	49	49.677	59	72.022	78	125.878
30	18.621	40	33.104	50	51.725	60	74.484	80	132.416

SHEAR @ 15,000 — VALUE FOR POWER DRIVEN RIVETS AND TURNED BOLTS IN REAMED HOLES — BEARING SINGLE = 32,000 DOUBLE = 40,000

RIVET DIAM.	⅝"		¾"		⅞"		1"		1⅛"	
SINGLE SHEAR	4600		6630		9020		11780		14910	
DOUBLE SHEAR	9200		13250		18040		23560		29820	
THICKNESS OF PLATE	BEARING (IN KIPS) 32.0	40.0	BEARING (IN KIPS) 32.0	40.0	BEARING (IN KIPS) 32.0	40.0	BEARING (IN KIPS) 32.0	40.0	BEARING (IN KIPS) 32.0	40.0
¼"	–	6.25	6.00	7.50	7.00	8.75	8.00	10.0	–	–
5/16"	–	7.81	–	9.38	8.75	10.9	10.0	12.5	11.3	14.1
⅜"	–	9.38	–	11.3	–	13.1	12.0	15.0	13.5	16.9
7/16"	–	–	–	13.1	–	15.3	–	17.5	–	19.7
½"	–	–	–	–	–	17.5	–	20.0	–	22.5
9/16"	–	–	–	–	–	–	–	22.5	–	25.3
⅝"	–	–	–	–	–	–	–	–	–	28.1

Sections revised according to Bulletin R-216-46 U.S. Dept. of Commerce Dated Feb. 15, 1946.

STEEL

Wt	S	t	V	R	G	d	b	r'	Wh
57	60.4	.57	67	67	13.8	9	8¼	2.12	
58	52.0	.51	58	57	12.2	8½	8¼	2.10	130C
18	43.2	.40	45	44	9.7	8½	8⅛	2.08	150S
40	35.5	.36	39	39	8.8	8¼	8⅛	2.04	
35	31.1	.31	33	33	7.6	8⅛	8	2.03	100C
31	27.4	.29	30	30	6.9	8	8	2.01	110S
28	24.3	.29	30	30	6.8	8	6½	1.62	80C
24	20.8	.24	25	25	5.9	7⅞	6½	1.61	90S
20	17.0	.25	26	25	6.0	8⅛	5¼	1.20	70C
7	14.1	.23	24	23	5.5	8	5¼	1.16	80S
5	11.8	.24	26	24	5.9	8⅛	4	.86	
3	9.9	.23	24	22	5.5	8	4	.83	50C
0	7.8	.17	18	16	4.1	7⅞	4	.82	60S
.3	28.9	.37	39	39	9.0	8	8	1.87	100C 110S
5	16.8	.32	27	33	7.7	6¾	6	1.52	
20	13.4	.26	21	26	6.2	6¼	6	1.50	60C 70S
.5	10.1	.24	19	24	5.8	6	6	1.45	
6	10.1	.26	21	26	6.2	6¼	4	.96	50C
2	7.24	.23	18	22	5.5	6	4	.90	60S
.5	5.07	.17	13	16	4.1	5⅞	4	.87	
5	15.7	.31	24	32	7.5	6	6	1.43	60C
0	12.9	.25	20	26	6.0	6	6	1.39	70S
.9	9.5	.31	20	32	7.5	5	5	1.20	40C
.5	9.9	.26	18	27	6.4	5⅛	5	1.28	50S
5	8.5	.24	16	24	5.8	5	5	1.26	
	5.2	.25	13	25	6.0	4	4	.94	
	5.45	.28	15	27	6.7	4⅛	4	.99	30C
	4.16	.22	11	22	5.3	4	4	.97	40S

Amer. Std. Channel Sect.

D	Wt	S	t	V	R	G	d	b	r'	Wh
18 [	58	74.5	.70	164	81	16.8	18	4¼	1.04	
	51.9	69.1	.60	140	69	14.4	18	4⅛	1.06	140C
	45.8	63.7	.50	117	58	12.0	18	4	1.09	170S
	42.7	61.0	.45	105	52	10.8	18	4	1.10	
15 [	50	53.6	.72	140	83	17.2	15	3¾	.87	120C
	40	46.2	.52	101	60	12.5	15	3½	.89	140S
	33.9	41.7	.40	78	46	9.6	15	3⅜	.91	
13 [	50	48.1	.79	133	91	19.0	13	4⅜	1.07	
	40	41.7	.56	94	65	13.4	13	4⅛	1.09	100C
	35	38.6	.45	76	52	10.8	13	4⅛	1.10	120S
	31.8	36.5	.38	64	43	9.1	13	4	1.11	
12 [	30	26.9	.51	80	56	12.2	12	3⅛	.77	80C
	25	23.9	.39	60	42	9.3	12	3	.79	100S
	20.7	21.4	.28	44	31	6.7	12	3	.81	
10 [	30	20.6	.67	88	72	16.2	10	3	.67	
	25	18.1	.53	68	56	12.6	10	2⅞	.68	70C
	20	15.7	.38	49	40	9.1	10	2¾	.70	90S
	15.3	13.4	.24	31	26	5.8	10	2⅝	.72	
9 [	20	13.5	.45	52	47	10.8	9	2⅝	.65	60C
	15	11.3	.28	33	30	6.8	9	2½	.67	70S
	13.4	10.5	.23	27	24	5.5	9	2⅜	.67	
8 [	18.75	10.9	.49	51	50	11.7	8	2½	.60	50C
	13.75	9.0	.30	32	31	7.3	8	2⅜	.62	60S
	11.5	8.1	.22	23	23	5.3	8	2¼	.63	
7 [	14.75	7.7	.42	38	43	10.1	7	2¼	.57	40C
	12.25	6.9	.31	29	33	7.5	7	2¼	.58	50S
	9.8	6.0	.21	19	22	50	7	2⅛	.59	
6 [	13.0	5.8	.44	34	45	10.5	6	2⅛	.53	30C
	10.5	5.0	.31	25	32	7.5	6	2	.53	40S
	8.2	4.3	.20	16	20	4.8	6	1⅞	.54	
5 [	9.0	3.5	.32	21	33	7.8	5	1⅞	.49	25C
	6.7	3.0	.19	12	19	4.6	5	1¾	.50	35S
4 [	7.25	2.3	.32	17	32	7.7	4	1¾	.46	
	5.4	1.9	.18	9	18	4.3	4	1⅝	.45	
3 [	6.0	1.4	.36	14	35	8.5	3	1⅝	.42	
	5.0	1.2	.26	10	26	6.2	3	1½	.41	10C
	4.1	1.1	.17	7	17	4.1	3	1⅜	.41	10S

Amer. Std. Beam Sect.

D	Wt	S	t	V	R	G	d	b	r'	Wh
24 I	120	250.9	.80	249	104	19.2	24	8	1.56	320C
	105.9	234.3	.62	195	82	15.0	24	7⅞	1.60	380S
	100	197.6	.75	233	92	17.9	24	7¼	1.29	
	90	185.8	.62	195	77	15.0	24	7⅛	1.32	280C
	79.9	173.9	.50	156	62	12.0	24	7	1.36	330S
20 I	95	160.0	.80	208	101	19.2	20	7¼	1.35	
	85	150.2	.65	170	82	15.7	20	7	1.38	240C
	75	126.3	.64	167	78	15.4	20	6⅜	1.17	280S
	65.4	116.9	.50	130	61	12.0	20	6¼	1.21	
18 I	70	101.9	.71	166	83	17.1	18	6¼	1.09	190C
	54.7	88.4	.46	108	54	11.0	18	6	1.15	230S
15 I	50	64.2	.55	107	63	13.2	15	5⅝	1.05	160C
	42.9	58.9	.41	80	47	9.8	15	5½	1.08	190S
12 I	50	50.3	.69	107	79	16.5	12	5½	1.05	
	40.8	44.8	.46	72	53	11.0	12	5¼	1.08	120C
	35	37.8	.43	67	48	10.3	12	5⅛	99	140S
	31.8	36.0	.35	55	39	8.4	12	5	1.01	
10 I	35	29.2	.59	77	64	14.3	10	5	.91	90C
	25.4	24.4	.31	40	34	7.4	10	4⅝	.97	110S
8 I	23.0	16.0	.44	46	46	10.6	8	4⅛	.81	70C
	18.4	14.2	.27	28	28	6.5	8	4	.84	80S
7 I	20.0	12.0	.45	41	47	10.8	7	3⅞	.74	50C
	15.3	10.4	.25	23	26	6.0	7	3⅝	.78	60S
6 I	17.25	8.7	.47	36	47	11.0	6	3⅝	.68	30C
	12.5	7.3	.23	18	24	5.5	6	3⅜	.72	40S
5 I	14.75	6.0	.49	32	50	12.0	5	3¼	.63	30C
	10.0	4.8	.21	14	21	5.0	5	3	.65	40S
4 I	9.5	3.3	.33	17	32	8.0	4	2¾	.58	30C
	7.7	3.0	.19	10	19	4.6	4	2⅝	.59	40S
3 I	7.5	1.9	.35	14	34	8.4	3	2½	.53	20C
	5.7	1.7	.17	7	17	4.1	3	2⅜	.53	30S

Allowable Working Stresses as per New York City Bldg. Code

Allowable Working Stresses for Columns (In Kips) Various Values of l/r (N.Y. Bldg. Code)

l/r	f	l/r	f	l/r	f	l/r	f	l/r	f	l/r	f
60	15.0	71	14.0	82	13.1	93	12.1	104	11.2	115	10.4
61	14.9	72	14.0	83	13.0	94	12.1	105	11.1	116	10.3
62	14.8	73	13.9	84	12.9	95	12.0	106	11.1	117	10.2
63	14.7	74	13.8	85	12.8	96	11.9	107	11.0	118	10.1
64	14.6	75	13.7	86	12.7	97	11.8	108	10.9	119	10.1
65	14.6	76	13.6	87	12.6	98	11.7	109	10.8	120	10.0
66	14.5	77	13.5	88	12.6	99	11.6	110	10.7	121	99
67	14.4	78	13.4	89	12.5	100	11.5	111	10.7	122	98
68	14.3	79	13.3	90	12.4	101	11.5	112	10.6	123	98
69	14.2	80	13.3	91	12.3	102	11.4	113	10.5	124	97
70	14.1	81	13.2	92	12.2	103	11.3	114	10.4	125	96

Allowable Fiber Stress and Proportion of Safe S for Beams Unsupported Laterally (N.Y. Bldg. Code)

l/b	f	S'/S	l/b	f	S'/S
15	18000	1.000	26	14948	.830
16	17730	.985	27	14657	.814
17	17475	.971	28	14368	.798
18	17212	.956	29	14080	.782
19	16942	.941	30	13793	.766
20	16667	.926	31	13510	.751
21	16387	.910	32	13228	.735
22	16103	.895	34	12674	.704
23	15817	.879	36	12136	.674
24	15528	.863	38	11614	.645
25	15238	.847	40	11111	.617

Deflection Coefficient - Uniform Loads 18,000#/□"

Defl. Inches = $\frac{\text{Defl. Coe.}}{d} = \frac{.01862\, L^2}{d}$

L	Defl. Coe.	L	Def. Coe.	L	Def. Coe.	L	Def. Coe.	L	Def. Coe.
21	8.211	31	17.894	41	31.301	51	48.432	62	71.578
22	9.012	32	19.067	42	32.846	52	50.350	64	76.270
23	9.850	33	20.277	43	34.430	53	52.306	66	81.112
24	10.725	34	21.525	44	36.048	54	54.298	68	86.102
25	11.638	35	22.810	45	37.707	55	56.325	70	91.238
26	12.587	36	24.132	46	39.400	56	58.395	72	96.530
27	13.574	37	25.491	47	41.133	57	60.499	74	101.967
28	14.598	38	26.887	48	42.901	58	62.640	76	107.553
29	15.659	39	28.321	49	44.708	59	64.819	78	113.288
30	16.758	40	29.792	50	46.550	60	67.032	80	119.168

Shear @ 13,500 — Value for Power Driven Rivets and Turned Bolts in Reamed Holes — Bearing Single = 24,000, Double = 30,000

Rivet Diam.	5/8"		3/4"		7/8"		1"		1⅛"	
Single Shear	4140		5960		8120		10600		13420	
Double Shear	8280		11930		16240		21200		26840	
Thickness of Plate	Bearing (in kips)		Bearing (in kips)		Bearing (in kips)		Bearing (in kips)		Bearing (in kips)	
	24.0	30.0	24.0	30.0	24.0	30.0	24.0	30.0	24.0	30.0
¼"	3.75	4.69	4.50	5.63	5.25	6.56	6.00	7.50	6.75	8.44
5/16"	–	5.86	5.63	7.03	6.56	8.20	7.50	9.38	8.44	10.55
⅜"	–	7.03	–	8.44	7.88	9.84	9.00	11.25	10.13	12.66
7/16"	–	8.20	–	9.84	–	11.48	10.50	13.13	11.81	14.77
½"	–	–	–	11.25	–	13.13	–	15.00	–	16.88
9/16"	–	–	–	–	–	14.77	–	16.88	–	18.98
⅝"	–	–	–	–	–	–	–	18.75	–	21.09

Value for Unfinished Bolts (left panel) — Bearing Single = 20,000, Double = 25,000 — Tension of Bolts @ 17,000#/□"

Bolt Diam.	5/8"		3/4"		7/8"		1"		Diam.	Tension (in kips)
Single Shear	3070		4420		6010		7850		¾"	3.62
Double Shear	6140		8840		12030		15710		⅞"	5.03
	Bearing (in kips)		Bearing (in kips)		Bearing (in kips)		Bearing (in kips)		1"	6.61
	20.0	25.0	20.0	25.0	20.0	25.0	20.0	25.0	1⅛	8.32
	.13	3.91	3.75	4.69	4.38	5.47	5.00	6.25	1¼	10.68
	–	4.88	–	5.86	5.47	6.84	6.25	7.81	1⅜	12.65
	–	5.86	–	7.03	–	8.20	7.50	9.38	1½	15.53
	–	–	–	8.20	–	9.57	–	10.9	1⅝	18.18
	–	–	–	–	–	10.9	–	12.5	1¾	20.93
	–	–	–	–	–	–	–	14.1	1⅞	24.59
	–	–	–	–	–	–	–	15.6	2"	27.60

Shear @ 10,000 — Value for Unfinished Bolts — Bearing Single = 16,000, Double = 20,000 — Tension of Bolts @ 12,000#/□"

Bolt Diam.	5/8"		3/4"		7/8"		1"		Diam.	Tension (in kips)
Single Shear	3070		4420		6010		7850		¾"	3.62
Double Shear	6140		8840		12030		15710		⅞"	5.03
Thickness of Plate	Bearing (in kips)		Bearing (in kips)		Bearing (in kips)		Bearing (in kips)		1"	6.61
	16.0	20.0	16.0	20.0	16.0	20.0	16.0	20.0	1⅛	8.32
¼"	2.5	3.13	3.0	3.75	3.5	4.38	4.0	5.0	1¼	10.68
5/16"	–	3.91	3.75	4.69	4.38	5.47	5.0	6.25	1⅜	12.65
⅜"	–	4.69	–	5.63	5.25	6.56	6.0	7.5	1½	15.53
7/16"	–	5.47	–	6.56	–	7.66	7.0	8.75	1⅝	18.18
½"	–	–	–	7.5	–	8.75	–	10.0	1¾	20.93
9/16"	–	–	–	8.44	–	9.85	–	11.25	1⅞	24.59
⅝"	–	–	–	–	–	10.94	–	12.50	2"	27.60

Properties of Angles

Size	S 1-1	Area	r 1-1	r 3-3	Size	S 1-1	S 2-2	Area	r 1-1	r 2-2	r 3-3
2½×2½×¼	.39	1.19	.77	.49	2½×2×¼	.38	.25	1.06	.78	.59	.42
3×3×¼	.58	1.44	.93	.59	3×2½×¼	.56	.40	1.31	.95	.75	.53
3×3×5/16	.71	1.78	.92	.59	3½×3×¼	.78	.59	1.56	1.11	.91	.63
3½×3½×¼	.79	1.69	1.09	.69	4×3×¼	1.0	.60	1.69	1.28	.90	.65
3½×3½×5/16	.98	2.09	1.08	.69	4×3×5/16	1.2	.73	2.09	1.27	.89	.65
4×4×¼	1.1	1.94	1.25	.80	5×3½×5/16	1.9	1.0	2.56	1.61	1.03	.77
4×4×5/16	1.3	2.40	1.24	.79	5×3½×⅜	2.3	1.2	3.05	1.60	1.02	.76
5×5×⅜	2.4	3.61	1.56	.99	5×3½×7/16	2.6	1.4	3.53	1.59	1.01	.76
6×6×⅜	3.5	4.36	1.88	1.19	6×4×⅜	3.3	1.6	3.61	1.93	1.17	.88
6×6×7/16	4.1	5.06	1.87	1.19	6×4×7/16	3.8	1.9	4.18	1.92	1.16	.87
6×6×½	4.6	5.75	1.86	1.18	6×4×½	4.3	2.1	4.75	1.91	1.15	.87

• Nomenclature •

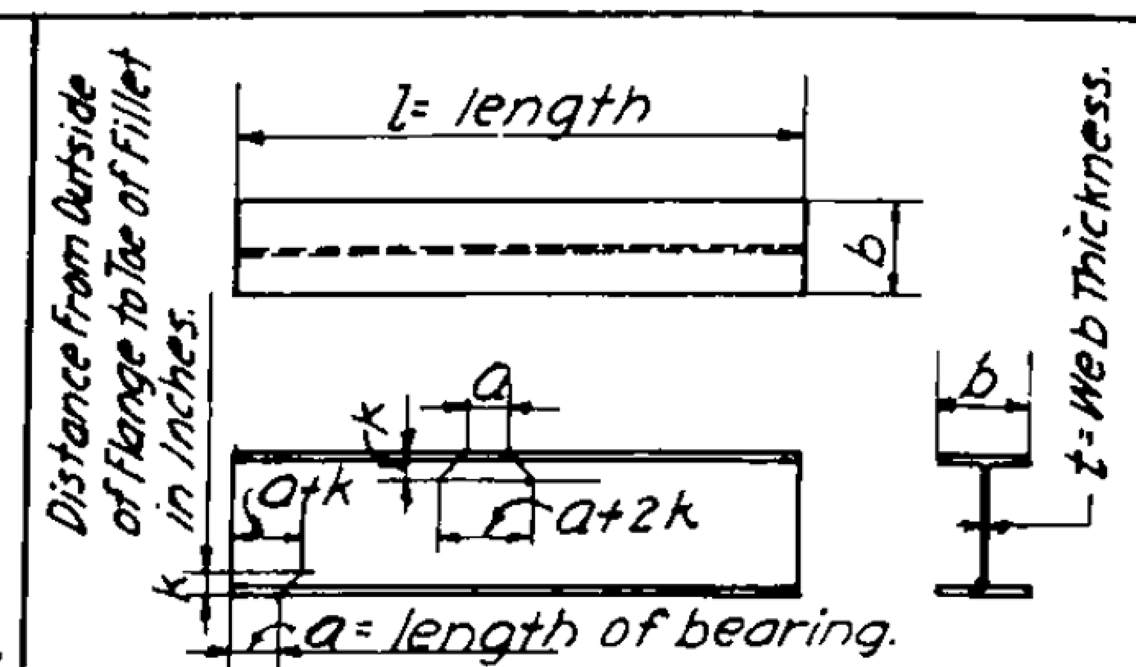
- D - Nominal depth in inches.
- Wt - Weight per foot in lbs.
- S - Section modulus.
- S' - Reduced S for unbraced flange.
- t - Web thickness in inches.
- V - Maximum web shear in kips for 13,000#/□"
- R - Allowable end reaction in kips for 3½" bearing (A.I.S.C.)
- G = Increase in R in kips for 1" additional bearing (A.I.S.C.)
- d - Actual depth in inches.
- b - Flange width in inches.
- Wh - Weight of haunch & section in #/'. S-Stone conc. C-Cinder conc.
- B - Bethlehem Steel Co. section.
- C - U.S. Steel Corp. section.
- I - American Standard section.
- l - Length of member in inches.
- r - Radius of gyration.
- r' - Least radius of gyration.
- f - Maximum allowable stress intensity per sq. inch.

STRUCTURAL - STEEL

RED LIGHTS IN STRUCTURAL STEEL DESIGN

BEAMS:

Compute section modulus and select size. See page 1-70.
Reaction must be less than allowable web shear V. See page 1-70.
Brace top flange laterally - $\frac{l}{b}$ = 40 Max. For stresses see page 1-70.
Strength of brace is to be not less than 2% of flange stress.
Consider relative deflection also. Limit of $\frac{l}{360}$ of span for live load is commonly used to prevent plaster cracks.
Horizontal shear is limited by $S=\frac{QV}{It}$*. S = Maximum at neutral axis.
Check web crippling at bearing concentrations. Use R & G, page 1-70, or maximum end reaction = 24,000(a+k); Max. interior load = 24,000t(a+2k).
Resolve loads on beams not set vertically in components parallel and perpendicular to web. Check extreme fiber stress.**
Eliminate beams subject to torsion wherever possible.



*S = Horizontal Unit Shear in #/□".
V = Vertical Shear at Section in Lbs.
I = Total Moment of Inertia in in.^{4}
Q = Static Moment = $A_1d_1 + A_2d_2$

**

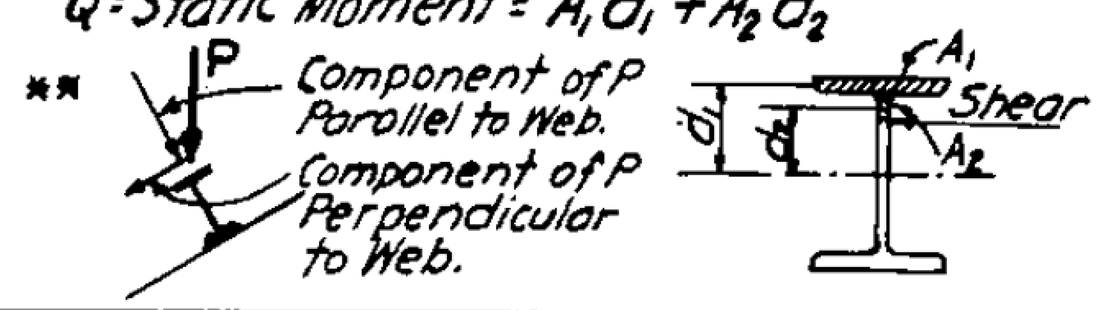
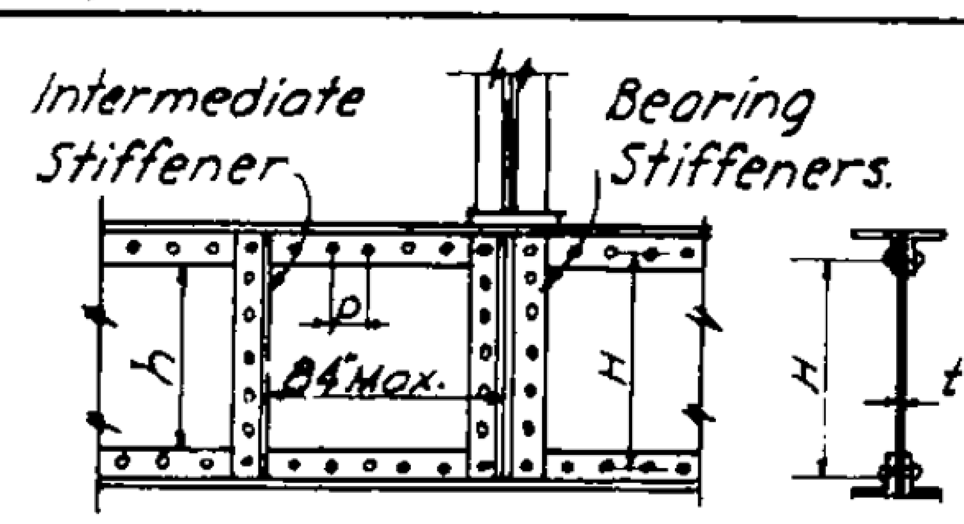


PLATE GIRDERS:

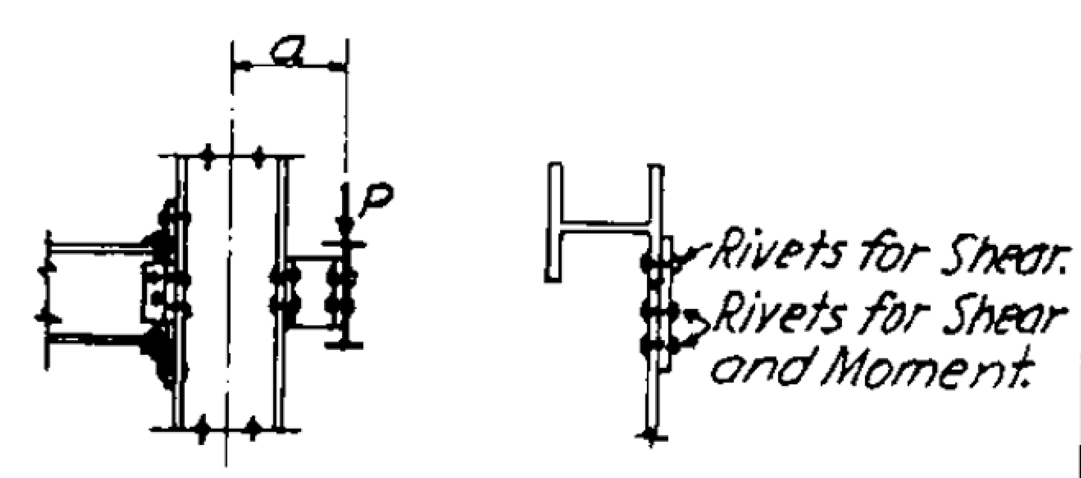
Design girder by moment of inertia of gross section using tables of "I". Correct for rivet hole deductions of more than 15%.
Check web shear - Allowable stress = 13,000#/□" for $\frac{h}{t} < 70$. Max. $\frac{h}{t}$ = 170.
Reduce web stress between $\frac{h}{t}$ = 70 and 170 to $v=\left(\frac{8000}{h/t}\right)^2$ or add stiffeners.
Stiffeners required at points in girder where $\frac{h}{t} \geq \frac{8000}{\sqrt{v}}$ - spaced $\frac{270{,}000t}{v}\sqrt[3]{\frac{vt}{h}}$ or 84" maximum.
Provide bearing stiffeners for all bearing concentrations.
Determine length of cover plates from bending moment diagram.
Determine rivet pitch, $p=\frac{RH}{V}$ (approx) or $\frac{RI}{VQ}$ (exact) - 3 dia. maximum.
For lateral bracing and deflection see beams.



R = Resistance of one rivet.
h = Unsupported Height of Web in Ins.
t = Web Thickness in Ins.
p = Rivet Pitch in Ins.
v = Unit Shear #/□"
H = Distance Between Rivet Lines in Ins.
For V, Q & I see Beams.

COLUMNS:

With direct load only select column from tables see page 1-74.
With direct load and bending, combined stresses should satisfy criterion $\frac{f_a}{F_A}+\frac{f_b}{F_B} \leq$ Unity, where f_a = direct stress, f_b = bending stress and F_A and F_B respective allowable unit stresses.
Brace all columns in two directions at splices. - Min. = 2% of load.
Eliminate eccentricity by using stiff connections or increase column section.
Distribute column moment above and below floor according to column stiffness.

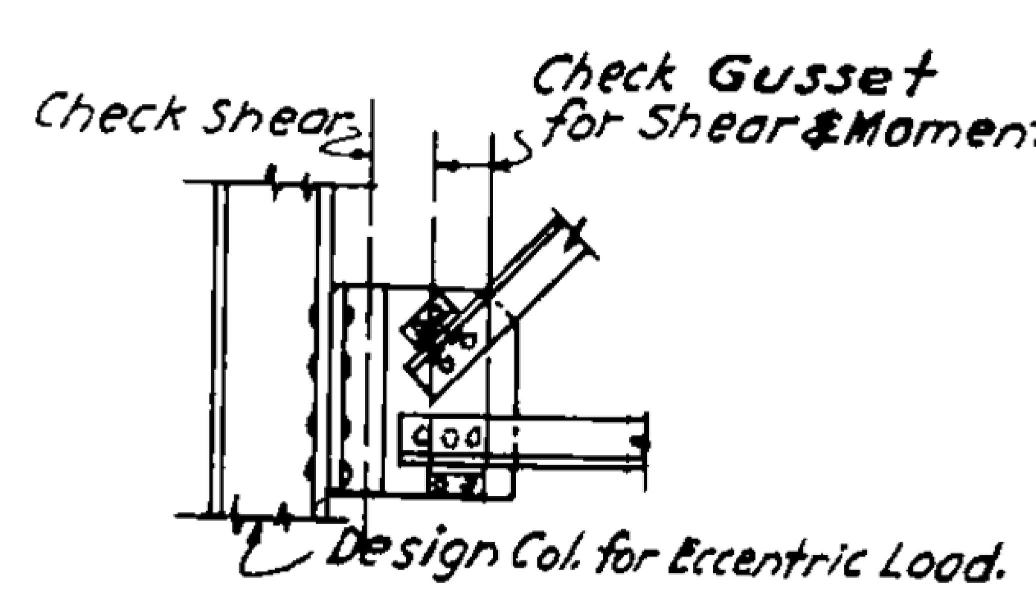


Moment in Column = Pa unless balanced by connection on opposite face.

Moment taken in beam to limit eccentricity in column.

TRUSSES:

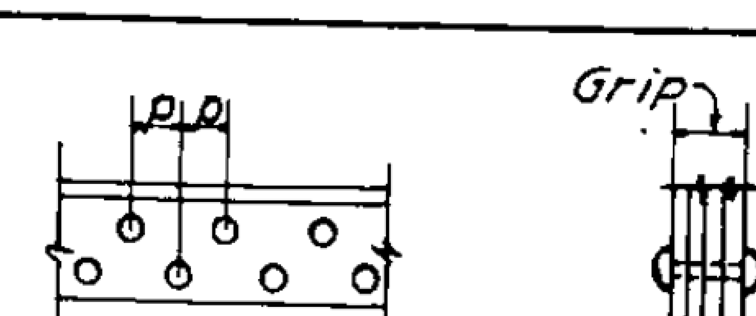
Determine stresses by graphic or analytical method.
For size of members see Angle strut Tables Pg. 1-76 to 1-79 & Angle Area Tab. Pg. 1-73
Check size and thickness of important gussets for shear and bending.
Check top chord for lateral bracing.
Chord members with direct load and bending should be designed for combined stresses.
Add clip angles to tension member to avoid eccentricity.



END GUSSET.

RIVETS:

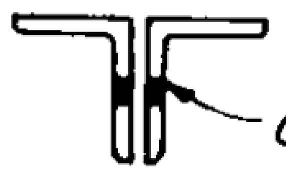
Rivet spacing should not be less than 3 times rivet diameter.
Rivet grip should not exceed 5 diameters. Number of rivets shall be increased 1% for each additional 1/16" in rivet grip.
For rivets with eccentric loads - see page 1-91.



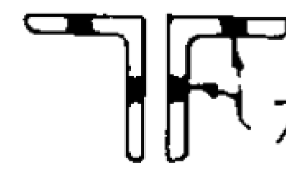
p = Rivet Pitch.

STRUCTURAL - STEEL

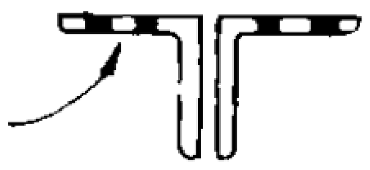
TABLE A- EFFECTIVE NET AREAS OF DOUBLE ANGLES IN TENSION WITH BOTH LEGS OF ANGLES ATTACHED.*



One Hole Out.



Two Holes Out.



(Size of holes 1/8" larger than rivet size.)

Size of Angles	Thickness (inches)	Gross Area of Angles (sq. in.)	Net Area in Square Inches: One Hole Out, Size of Hole 7/8"	One Hole Out 1"	One Hole Out 1 1/8"	Two Holes Out, Size of Hole 7/8"	Two Holes Out 1"	Two Holes Out 1 1/8"
8 x 8	1 1/8	33.46	31.50	31.21	30.92	29.54	28.96	28.38
	1	30.00	28.25	28.00	27.75	26.50	26.00	25.50
	7/8	26.46	24.92	24.71	24.50	23.38	22.96	22.54
	3/4	22.88	21.56	21.38	21.20	20.24	19.88	19.52
	5/8	19.22	18.12	17.97	17.82	17.02	16.72	16.42
	1/2	15.50	14.62	14.50	14.38	13.74	13.50	13.26
8 x 6	1	26.00	24.25	24.00	23.75	22.50	22.00	21.50
	7/8	22.96	21.42	21.21	21.00	19.88	19.46	19.04
	3/4	19.88	18.56	18.38	18.20	17.24	16.88	16.52
	5/8	16.72	15.62	15.47	15.32	14.52	14.22	13.92
	1/2	13.50	12.62	12.50	12.38	11.74	11.50	11.26
6 x 6	1	22.00	20.25	20.00	19.75	18.50	18.00	17.50
	7/8	19.46	17.92	17.71	17.50	16.38	15.96	15.54
	3/4	16.88	15.56	15.38	15.20	14.24	13.88	13.52
	5/8	14.22	13.12	12.97	12.82	12.02	11.72	11.42
	1/2	11.50	10.62	10.50	10.38	9.74	9.50	9.26
	3/8	8.72	8.06	7.97	7.88	7.40	7.22	7.04
5 x 5	1	18.00	16.25	16.00	15.75	14.50	14.00	13.50
	7/8	15.96	14.42	14.21	14.00	12.88	12.46	12.04
	3/4	13.88	12.56	12.38	12.20	11.24	10.88	10.52
	5/8	11.72	10.62	10.47	10.32	9.52	9.22	8.92
	1/2	9.50	8.62	8.50	8.38	7.74	7.50	7.26
	3/8	7.22	6.56	6.47	6.38	5.90	5.72	5.54
8 x 4	1	22.00	20.25	20.00	19.75	18.50	18.00	17.50
	7/8	19.46	17.92	17.71	17.50	16.38	15.96	15.54
	3/4	16.88	15.56	15.38	15.20	14.24	13.88	13.52
	5/8	14.22	13.12	12.97	12.82	12.02	11.72	11.42
	1/2	11.50	10.62	10.50	10.38	9.74	9.50	9.26
7 x 4	1	20.00	18.25	18.00	17.75	16.50	16.00	15.50
	7/8	17.72	16.18	15.97	15.76	14.64	14.22	13.80
	3/4	15.38	14.06	13.88	13.70	12.74	12.38	12.02
	5/8	12.98	11.88	11.73	11.58	10.78	10.48	10.18
	1/2	10.50	9.62	9.50	9.38	8.74	8.50	8.26
	3/8	7.98	7.32	7.23	7.14	6.66	6.48	6.30
6 x 4	7/8	15.96	14.42	14.21	14.00	12.88	12.46	12.04
	3/4	13.88	12.56	12.38	12.20	11.24	10.88	10.52
	5/8	11.72	10.62	10.47	10.32	9.52	9.22	8.92
	1/2	9.50	8.62	8.50	8.38	7.74	7.50	7.26
	3/8	7.22	6.56	6.47	6.38	5.90	5.72	5.54

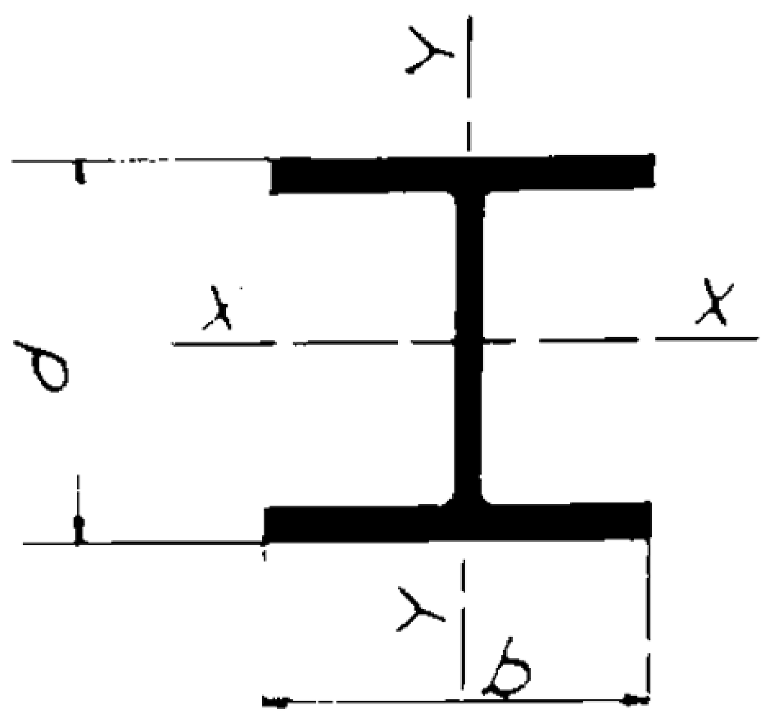
Size of Angles	Thickness (inches)	Gross Area of Angles (sq. in.)	Net Area in Square Inches: One Hole Out, Size of Hole 7/8"	One Hole Out 1"	One Hole Out 1 1/8"	Two Holes Out, Size of Hole 7/8"	Two Holes Out 1"	Two Holes Out 1 1/8"
5 x 3 1/2	3/4	11.62	10.30	10.12	9.94	8.98	8.62	8.26
	5/8	9.84	8.74	8.59	8.44	7.64	7.34	7.04
	1/2	8.00	7.12	7.00	6.88	6.24	6.00	5.76
	3/8	6.10	5.44	5.35	5.26	4.78	4.60	4.42
4 x 4	3/4	10.88	9.56	9.38	9.20	8.24	7.88	7.52
	5/8	9.22	8.12	7.97	7.82	7.02	6.72	6.42
	1/2	7.50	6.62	6.50	6.38	5.74	5.50	5.26
	3/8	5.72	5.06	4.97	4.88	4.40	4.22	4.04
	1/4	3.88	3.44	3.38	3.32	3.00	2.88	2.76
4 x 3 1/2	3/4	10.12	8.80	8.62	8.44	7.48	7.12	6.76
	5/8	8.60	7.50	7.35	7.20	6.40	6.10	5.80
	1/2	7.00	6.12	6.00	5.88	5.24	5.00	4.76
	3/8	5.34	4.68	4.59	4.50	4.02	3.84	3.66
4 x 3	5/8	7.96	6.86	6.71	—	5.76	5.46	—
	1/2	6.50	5.62	5.50	—	4.74	4.50	—
	3/8	4.96	4.30	4.21	—	3.64	3.46	—
	1/4	3.38	2.94	2.88	—	2.50	2.38	—
3 1/2 x 3 1/2	3/4	9.38	8.06	7.88	—	6.74	6.38	—
	5/8	7.96	6.86	6.71	—	5.76	5.46	—
	1/2	6.50	5.62	5.50	—	4.74	4.50	—
	3/8	4.96	4.30	4.21	—	3.64	3.46	—
	1/4	3.38	2.94	2.88	—	2.50	2.38	—
3 1/2 x 3	5/8	7.34	6.24	6.09	—	5.14	4.84	—
	1/2	6.00	5.12	5.00	—	4.24	4.00	—
	3/8	4.60	3.94	3.85	—	3.28	3.10	—
	1/4	3.12	2.68	2.62	—	2.24	2.12	—
3 x 3	5/8	6.72	5.62	5.47	—	4.52	4.22	—
	1/2	5.50	4.62	4.50	—	3.74	3.50	—
	3/8	4.22	3.56	3.47	—	2.90	2.72	—
	1/4	2.88	2.44	2.38	—	2.00	1.88	—
3 x 2 1/2	3/8	3.84	3.18		—	2.52		—
	1/4	2.62	2.18		—	1.74		—
2 1/2 x 2 1/2	1/2	4.50	3.62		—	2.74		—
	3/8	3.46	2.80		—	2.14		—
	1/4	2.38	1.94		—	1.50		—
2 1/2 x 2	3/8	3.10	2.44		—	1.78	—	—
	1/4	2.12	1.68		—	1.24		—
2 x 2	3/8	2.72	2.06		—	1.40		—
	1/4	1.88	1.44		—	1.00		—

* With only one leg of each angle attached reduce net area in Table A by one-half the area of the unattached legs.

If single angle is used, effective area equals one-half net area in Table A less one-half area of the outstanding leg.

STRUCTURAL

ALLOWABLE CONCENTRIC LOADS IN KIP



Formula:

$$F_A = 17{,}000 - 0.485\frac{l^2}{r^2} \quad \text{for } \frac{l}{r} < 120.$$

$$F_A = \frac{18{,}000}{1+\frac{l^2}{18000r^2}} \quad \text{for } \frac{l}{r} = 120 \text{ to } 200.$$

For columns subject to axial load and bending-combined stresses $\frac{f_a}{F_A} + \frac{f_b}{F_B}$ shall be less than unity.

Nomenclature:

l = Unbraced length of column in inches.
r = Radius of gyration in inches.
F_A = Allowable axial stress #/□".
F_B = Allowable bending stress #/□".
f_a = Actual axial stress #/□".
f_b = Actual bending stress #/□".
A = Area of column, Sq. In.

NOM. SIZE	WT. LB/FT	AREA SQ.IN.	DIMENSION d	DIMENSION b	AXIS X-X S_x	AXIS X-X B_x	AXIS Y-Y S_Y	AXIS Y-Y B_Y	RATIO r_x/r_y	10	12	14	16	18	20	22	24	26	28	30
										UNBRACED LENGTH IN FEET FOR LEAST RADIUS OF GYRATION										
6	15.5	4.57	6	6	9.7	0.46	3.2	1.44	1.77	63	56	48	42	37	33	29	26			
*	18	5.30	6⅛	6	11.5	0.45	3.9	1.36	1.77	73	66	57	49	44	39	35	31			
	20	5.89	6¼	6	13.1	0.44	4.5	1.34	1.77	82	74	64	56	49	44	39	35			
*	22.5	6.61	6¼	6	14.8	0.44	5.1	1.33	1.77	92	83	73	63	56	50	44	40			
	25	7.35	6⅜	6	16.4	0.44	5.7	1.32	1.77	103	93	82	70	63	56	50	44			
*	27.5	8.09	6½	6⅛	18.0	0.44	6.3	1.31	1.77	114	103	90	78	69	62	55	49			
8	24	7.06	7⅞	6½	20.8	0.34	5.6	1.26	2.12	101	93	83	71	64	57	51	46	41		
	28	8.22	8	6½	24.3	0.34	6.6	1.24	2.13	118	108	97	84	75	66	60	54	49		
	31	9.12	8	8	27.4	0.33	9.2	0.99	1.73	139	132	124	115	104	92	84	77	70	64	59
*	33	9.70	8	8	29.3	0.33	9.9	0.98	1.73	148	141	133	123	111	99	90	82	75	69	63
	35	10.30	8⅛	8	31.1	0.33	10.6	0.97	1.72	158	150	141	131	119	105	96	88	80	74	67
	40	11.76	8¼	8⅛	35.5	0.33	12.1	0.97	1.73	180	172	161	149	136	121	110	100	92	84	78
	48	14.11	8½	8⅛	43.2	0.33	15.0	0.94	1.74	217	207	195	182	166	149	134	123	113	104	95
	58	17.06	8¾	8¼	52.0	0.33	18.2	0.94	1.74	263	251	237	221	202	182	164	150	138	127	117
	67	19.70	9	8¼	60.4	0.33	21.4	0.92	1.75	304	291	275	256	236	212	190	175	161	148	136
10	33	9.71	9¾	8	35.0	0.28	9.2	1.06	2.16	147	139	130	119	107	94	86	79	72	66	60
*	37	10.88	9⅞	8	39.9	0.27	10.6	1.03	2.16	165	157	147	135	122	107	98	90	82	75	69
	39	11.47	10	8	42.2	0.27	11.2	1.02	2.16	174	165	155	142	129	113	104	95	87	79	73
	45	13.24	10⅛	8	49.1	0.27	13.3	1.00	2.17	202	192	180	166	150	133	121	111	102	93	85
	49	14.40	10	10	54.6	0.26	18.6	0.77	1.71	229	222	214	205	194	182	169	155	141	131	122
	54	15.88	10⅛	10	60.4	0.26	20.7	0.77	1.71	253	246	237	227	215	202	188	172	157	146	136
	60	17.66	10¼	10⅛	67.1	0.26	23.1	0.77	1.72	282	274	264	252	240	226	210	193	175	163	152
	66	19.41	10⅜	10⅛	73.7	0.26	25.5	0.76	1.72	309	301	290	278	264	249	231	213	193	180	168
	72	21.88	10½	10⅛	80.1	0.26	27.9	0.76	1.72	338	328	317	303	289	272	253	233	211	197	184
	77	22.67	10⅝	10¼	86.1	0.26	30.1	0.75	1.73	362	352	340	326	310	292	272	250	227	212	198
	89	26.19	10⅞	10¼	99.7	0.26	35.2	0.74	1.73	419	407	394	378	360	340	317	293	267	247	231
	100	29.43	11⅛	10⅜	112.4	0.26	39.9	0.74	1.74	471	458	443	425	406	383	359	332	302	280	262
	112	32.92	11⅜	10⅜	126.3	0.26	45.2	0.73	1.75	528	513	496	477	455	431	403	374	341	315	295
*	124	36.46	11⅝	10½	139.9	0.26	50.4	0.72	1.75	585	569	551	530	506	479	450	417	382	352	329
*	136	40.03	11⅞	10⅝	154.4	0.26	56.0	0.71	1.76	643	626	606	584	558	529	498	463	425	390	365
12	40	11.77	12	8	51.9	0.23	11.0	1.07	2.64	178	169	157	144	129	115	104	95	87	79	73
	45	13.24	12	8	58.2	0.23	12.4	1.07	2.65	200	190	177	162	145	129	117	107	98	89	82
	50	14.71	12¼	8⅛	64.7	0.23	14.0	1.05	2.64	223	212	198	182	163	144	132	120	110	101	92
	53	15.59	12	10	70.7	0.22	19.2	0.81	2.11	248	240	230	220	208	194	179	163	149	139	129
	58	17.06	12¼	10	78.1	0.22	21.4	0.80	2.10	271	263	253	241	229	214	198	181	165	154	143
*	64	18.83	12¼	10	85.8	0.22	23.7	0.79	2.11	299	290	279	267	253	237	219	200	182	170	158
	65	19.11	12⅛	12	88.0	0.22	29.1	0.66	1.75	310	304	296	288	278	266	254	241	226	210	193
	72	21.16	12¼	12	97.5	0.22	32.4	0.65	1.75	344	337	328	319	308	296	282	268	252	234	216
	79	23.22	12⅜	12⅛	107.1	0.22	35.8	0.65	1.75	378	370	361	350	338	325	310	294	277	258	238
	85	24.98	12½	12⅛	115.7	0.22	38.9	0.64	1.75	406	398	388	377	365	351	335	318	300	280	258
	92	27.06	12⅝	12⅛	125.0	0.22	42.2	0.64	1.75	440	431	421	409	395	380	364	346	326	304	281
	99	29.09	12¾	12¼	134.7	0.22	45.7	0.64	1.76	473	464	453	440	426	410	392	372	351	328	303
	106	31.19	12⅞	12¼	144.5	0.22	49.2	0.63	1.76	508	498	486	473	457	440	421	400	378	354	327
	120	35.31	13⅛	12⅜	163.4	0.22	56.0	0.63	1.76	575	564	551	536	519	500	478	455	430	403	374
	133	39.11	13⅜	12⅜	182.5	0.21	63.1	0.62	1.77	638	626	611	595	576	555	532	507	480	451	419
*	147	43.24	13⅝	12½	201.8	0.21	70.2	0.62	1.77	705	692	677	659	638	616	591	563	533	501	466
	161	47.38	13⅞	12½	222.2	0.21	77.7	0.61	1.78	773	759	742	723	701	676	649	619	587	552	515
*	176	51.79	14⅛	12⅝	242.6	0.21	85.4	0.61	1.79	845	830	812	791	767	741	712	679	645	607	566
	190	55.86	14⅜	12⅝	263.2	0.21	93.1	0.60	1.79	913	896	877	855	830	802	771	737	700	660	617

* Obsolete section – not being rolled.

STEEL

…FOR WIDE FLANGE COLUMNS A.I.S.C. 1941

…ction Moduli in $In.^3$.
…nding Factors.
…Moment of Inertia - $In.^4$
…Moment of Inertia - $In.^4$
…f radii of gyration.

… "X" axis must not be greater … times l for "Y" axis.

EXAMPLE: Design of a column with eccentric loading.
Given: Axial load P = 400 K; moment about X axis, M = 1900 in. kips, l = 18'-0". Required: To find size of column.
Solution: Assume 14" column, B_x = .18. Equivalent direct load from bending = $M \cdot B_x$ = 1900 x .18 = 342 kips.
Approximate column load = 400 + 342 = 742 kips. From table for load and length approximate column size = 14 WF 167. Check column size using criterion $\frac{f_a}{F_A} + \frac{f_b}{F_B} \overline{\gtrless} 1$. $F_A = \frac{\text{load in table}}{A}$; F_B = 20,000 #/□".

Using 14 WF 167; F_A = 15,600 #/□"; F_B = 20,000 #/□"; $f_a = \frac{P}{A}$ = 8140 #/□"; $f_b = \frac{M}{S}$ = 7120 #/□". Criterion gives .876 - col. too strong.
Using 14 WF 150; F_A = 15,600 #/□"; F_B = 20,000 #/□"; f = 9060 #/□"; f_b = 7900 #/□". " " .98 - correct size.

…A	DIMENSION		AXIS X-X		AXIS Y-Y		RATIO	UNBRACED LENGTH IN FEET FOR LEAST RADIUS OF GYRATION														
…N.	d	b	S_x	B_x	S_Y	B_Y	r_x/r_Y	10	12	14	16	18	20	22	24	26	28	30	32	34	36	40
…55	13 5/8	8	62.7	0.20	11.3	1.12	3.08	190	179	166	152	135	120	109	99	91	83	76				
…11	13 7/8	8	70.2	0.20	12.8	1.10	3.07	213	201	187	171	152	135	123	112	102	93	85				
…59	14	8	77.8	0.20	14.3	1.09	3.07	235	222	207	190	169	150	137	125	114	104	95	87			
…06	14	8 1/8	85.0	0.20	15.7	1.09	3.07	258	244	227	208	186	165	151	137	125	114	105	96			
…94	13 7/8	10	92.2	0.19	21.5	0.83	2.44	284	275	264	252	238	222	204	185	170	158	147	137	127	118	103
…00	14	10	103.0	0.19	24.1	0.83	2.45	317	307	295	281	265	248	228	207	190	177	164	153	142	133	116
…76	14 1/4	10 1/8	112.3	0.19	26.5	0.82	2.44	345	334	321	307	290	271	250	228	208	194	180	168	156	146	127
…14	14	12	121.1	0.19	34.5	0.67	2.03	372	364	355	344	332	319	304	288	270	250	230	216	204	192	170
…71	14 1/8	12	130.9	0.19	37.5	0.66	2.03	401	393	383	372	359	345	329	311	292	272	250	234	221	208	195
…56	14	14 1/2	138.1	0.19	48.2	0.53	1.66	422	416	409	401	392	382	372	360	346	332	317	301	284	265	238
…94	14 1/8	14 1/2	150.6	0.19	52.8	0.53	1.66	461	455	447	439	429	418	406	393	379	364	347	330	311	291	261
…76	14 1/4	14 5/8	163.6	0.19	57.6	0.53	1.67	499	493	485	475	465	453	441	427	411	395	377	358	338	317	283
…55	14 3/8	14 5/8	176.3	0.19	62.2	0.53	1.67	539	531	523	513	502	490	476	461	444	426	408	387	366	343	306
…19	14 1/2	14 5/8	189.4	0.19	67.1	0.52	1.67	578	570	561	551	539	525	511	495	477	459	438	417	394	370	330
…3	14 5/8	14 3/4	202.0	0.19	71.8	0.52	1.67	616	608	598	587	575	561	545	528	510	490	469	446	421	396	353
…8	14 3/4	14 3/4	216.0	0.19	77.0	0.52	1.67	660	651	641	629	616	601	585	567	547	526	503	478	453	425	379
…5	14 3/4	15 1/2	226.7	0.19	85.2	0.49	1.59	693	685	675	664	652	638	622	605	586	566	544	522	497	471	416
…8	14 7/8	15 1/2	240.2	0.18	90.6	0.49	1.60	730	722	712	700	687	672	656	638	619	598	575	552	526	499	440
…7	15	15 1/2	253.4	0.18	95.8	0.49	1.60	770	761	750	738	724	709	692	673	653	631	607	582	556	527	465
…9	15 1/8	15 5/8	267.3	0.18	101.3	0.49	1.60	813	804	793	780	765	749	731	712	690	667	643	616	588	558	493
…3	15 1/4	15 5/8	281.9	0.18	107.1	0.48	1.60	857	847	836	822	807	790	771	751	728	704	678	651	621	589	522
…7	15 3/8	15 5/8	295.8	0.18	112.7	0.48	1.61	896	886	874	860	844	827	807	786	763	738	711	683	652	619	549
…3	15 1/2	15 3/4	310.0	0.18	118.4	0.48	1.61	940	930	917	903	886	868	848	825	801	775	747	717	685	651	578
…9	15 5/8	15 3/4	324.9	0.18	124.4	0.48	1.61	984	973	960	945	928	909	888	865	840	812	783	752	719	684	607
…7	15 3/4	15 3/4	339.2	0.18	130.2	0.48	1.61	1029	1018	1004	988	971	951	928	904	878	850	819	787	753	716	637
…6	15 7/8	15 7/8	352.6	0.18	135.6	0.48	1.62	1067	1055	1041	1025	1007	986	963	938	911	882	851	818	782	744	662
…5	16	15 7/8	367.8	0.18	141.8	0.47	1.61	1112	1100	1086	1069	1050	1029	1005	980	952	927	889	854	818	779	694
…9	16 1/8	15 7/8	382.2	0.18	147.7	0.47	1.62	1156	1143	1128	1111	1091	1070	1045	1019	990	959	925	890	851	811	724
…3	16 1/4	16	397.4	0.18	153.9	0.47	1.62	1200	1187	1171	1154	1133	1110	1085	1058	1029	996	962	925	886	844	753
…8	16 3/8	16	412.0	0.18	159.9	0.47	1.62	1244	1230	1214	1196	1175	1152	1126	1098	1067	1034	998	960	920	877	784
…3	16 1/2	16	427.4	0.18	166.1	0.47	1.63	1288	1274	1258	1239	1217	1193	1166	1137	1106	1071	1035	995	954	910	814
…2	16 5/8	16 1/8	442.0	0.18	172.2	0.47	1.63	1331	1317	1300	1280	1258	1234	1206	1176	1144	1108	1071	1031	988	942	843
…7	16 3/4	16 1/8	465.5	0.18	181.8	0.46	1.63	1400	1386	1368	1348	1325	1299	1270	1239	1205	1168	1130	1087	1043	995	892
…0	17	16 1/8	488.2	0.18	191.2	0.46	1.64	1464	1449	1431	1410	1386	1359	1330	1298	1262	1224	1184	1140	1094	1045	938
…0	17 1/4	16 1/4	511.9	0.18	201.0	0.46	1.64	1533	1516	1497	1476	1450	1423	1392	1359	1322	1283	1240	1195	1147	1095	984
…2	16 3/4	16 3/4	492.8	0.19	195.7	0.48	1.59	1562	1546	1526	1503	1478	1449	1417	1382	1345	1303	1260	1213	1163	1110	995
…3	17 3/8	16 1/4	535.8	0.18	210.9	0.46	1.65	1602	1585	1565	1542	1517	1488	1456	1422	1384	1343	1299	1252	1202	1149	1035
…	17 1/2	16 3/8	559.4	0.18	220.8	0.46	1.65	1671	1654	1633	1610	1584	1554	1521	1485	1446	1404	1358	1310	1259	1203	1085
…3	17 3/4	16 3/8	583.6	0.18	230.9	0.45	1.65	1739	1722	1701	1676	1649	1619	1584	1547	1507	1464	1417	1367	1314	1258	1135
…3	18	16 1/2	608.1	0.18	241.1	0.45	1.66	1808	1789	1768	1742	1714	1683	1648	1610	1567	1522	1474	1423	1367	1309	1183
…1	18 1/8	16 1/2	632.2	0.18	251.3	0.45	1.66	1877	1858	1836	1810	1781	1749	1713	1673	1630	1584	1534	1481	1424	1364	1234
…3	18 1/4	16 5/8	656.9	0.18	261.6	0.45	1.66	1945	1925	1902	1876	1846	1813	1775	1736	1691	1643	1593	1538	1480	1419	1285
…	18 1/2	16 5/8	682.1	0.18	272.1	0.44	1.67	2014	1994	1971	1944	1913	1878	1840	1798	1753	1704	1652	1595	1536	1472	1334
…	18 3/4	16 3/4	707.4	0.18	282.7	0.44	1.67	2083	2062	2038	2011	1979	1944	1905	1862	1815	1765	1711	1653	1593	1528	1386

Note: Values to right of heavy line are for l/r ratios between 120 and 200.
The 14 WF 320 section is used as column core.

… revised according to Bulletin R216-46; U.S. Dept. of Commerce Feb 15, 1946

STRUCTURAL - STEEL

TABLE A-ALLOWABLE CONCENTRIC LOADS ON STRUTS OF ONE ANGLE (IN KIPS).

A.I.S.C. CODE 1941 MAXIMUM $l/r = 120$

Size L	t	Unbraced Length 6	7	8	9	10	11	12	13	14	15	Max. L
8 x 8	1⅛	267	261	254	246	237	227	215	203	190	175	15.6
	1	239	234	228	220	212	203	193	182	170	158	15.6
	⅞	[illegible]	207	200	195	187	179	171	162	151	141	15.7
	¾	183	178	173	168	162	155	148	140	131	122	15.7
	⅝	154	150	146	142	136	131	125	118	111	103	15.8
	½	124	121	118	114	110	106	101	95	90	83	15.9
8 x 6	1	201	194	185	176	166	154	141	130			12.8
	⅞	177	172	164	156	146	136	125	115			12.8
	¾	154	149	142	135	127	118	109	99			12.9
	⅝	129	125	119	114	107	100	92	84			12.9
	½	105	101	97	92	87	81	74	67			13.0

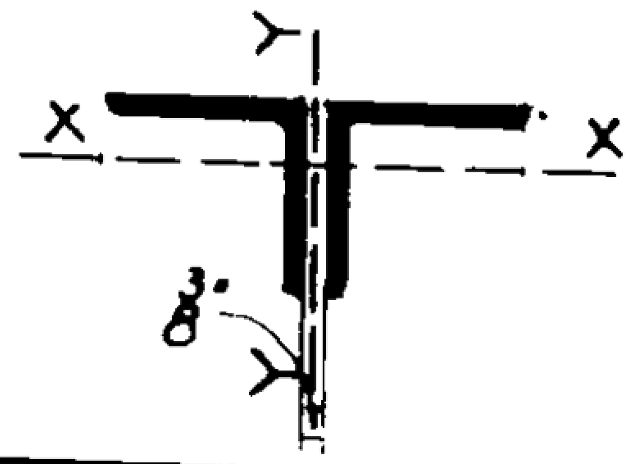
Size L	t	Unbraced Length. 3	4	5	6	7	8	9	10	11	12	Max. L
6 x 6	1	182	178	173	167	159	151	141	131	119	110	11.7
	⅞	161	158	153	147	141	134	125	116	105	97	11.7
	¾	140	137	133	128	122	116	108	100	91	84	11.7
	⅝	118	115	112	108	103	98	92	85	78	71	11.8
	½	95	93	91	87	84	79	74	69	63	57	11.8
	⅜	72	71	69	66	63	60	57	53	48	44	11.9
5 x 5	1	147	142	136	129	120	110	99	90			9.7
	⅞	130	126	121	114	107	98	88	80			9.7
	¾	113	110	105	99	93	85	76	69			9.7
	⅝	96	93	89	84	79	72	65	59			9.8
	½	78	75	72	68	64	58	53	47			9.8
	⅜	59	57	55	52	48	44	40	36			9.8
8 x 4	1	177	170	160	149	135	119	110				8.5
	⅞	157	150	141	132	120	105	97				8.5
	¾	136	130	122	114	104	91	84				8.5
	⅝	115	110	104	97	88	78	71				8.6
	½	93	89	84	78	71	63	57				8.6
7 x 4	1	161	154	145	136	123	108	100				8.5
	⅞	143	137	130	121	110	97	89				8.6
	¾	124	119	113	105	95	84	77				8.6
	⅝	105	100	95	88	80	71	65				8.6
	½	85	82	77	72	66	58	52				8.7
	⅜	64	62	59	55	50	45	40				8.7
6 x 4	⅞	129	124	117	109	99	88	80				8.6
	¾	112	107	102	95	86	76	69				8.6
	⅝	95	91	86	80	73	64	59				8.6
	½	77	74	70	65	59	53	47				8.7
	⅜	58	56	53	50	45	41	36				8.8

Size L	t	Unbraced Length 2	3	4	5	6	7	8	Max. L
5x3½	¾	96	92	87	81	73	64	58	7.5
	⅝	81	78	74	68	62	54	49	7.5
	½	66	63	60	56	50	44	40	7.5
	⅜	50	49	46	43	39	34	30	7.6
4 x 4	¾	90	87	82	77	70	62	54	7.8
	⅝	76	74	70	65	59	53	46	7.8
	½	62	60	57	53	48	43	37	7.8
	⅜	47	46	44	41	37	33	29	7.9
	¼	32	31	30	28	25	23	19	8.0
4 x 3½	¾	83	80	75	69	61	53	51	7.2
	⅝	71	68	64	59	52	45	43	7.2
	½	58	55	52	48	43	36	35	7.2
	⅜	44	42	40	37	33	28	27	7.3
4 x 3	⅝	65	61	57	51	43	40		6.4
	½	53	50	46	41	35	32		6.4
	⅜	40	38	35	32	27	25		6.4
	¼	28	26	24	22	19	17		6.5
3½x3½	¾	77	73	68	62	54	47		6.8
	⅝	65	62	58	52	46	40		6.8
	½	53	51	47	43	38	32		6.8
	⅜	41	39	36	33	29	25		6.9
	¼	28	26	25	23	20	17		6.9
3½x3	⅝	60	56	52	46	38	37		6.2
	½	49	46	42	37	31	30		6.2
	⅜	37	35	32	29	24	23		6.2
	¼	25	24	22	20	17	16		6.3
3 x 3	⅝	54	51	46	40	34			5.8
	½	44	42	37	32	27			5.8
	⅜	34	32	29	25	21			5.8
	¼	23	22	20	17	14			5.9
3x2½	⅜	31	28	25	20	19			5.2
	¼	21	19	17	15	13			5.3
2½x2½	½	36	32	28	22				4.9
	⅜	27	25	21	17				4.9
	¼	19	17	15	12				4.9
2½x2	⅜	24	21	16	15				4.2
	¼	16	14	12	11				4.2
2x2	⅜	20	17	14					3.9
	¼	14	12	9					3.9

In using this table allowance must be made for eccentric loading. Numbers at right of heavy lines give loads for maximum length "L".

STRUCTURAL - STEEL

TABLE A-ALLOWABLE CONCENTRIC LOADS ON STRUTS FORMED BY TWO EQUAL ANGLES IN KIPS.



A.I.S.C. CODE-1941

MAXIMUM $l/r = 120$

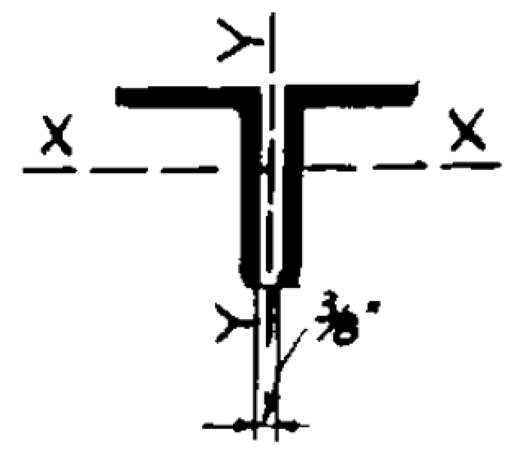
Size	t	Area	r X-X Axis	r Y-Y Axis	Unbraced Length in Feet 3/8" Back to Back																					
					Axis X-X										* Max	Axis Y-Y										* Max
					4	5	6	8	10	12	14	16	18	20	L	6	7	8	10	12	14	16	18	20	22	24	L
8 x 8	1 1/8	33.46	2.42	3.55	562	559	554	543	529	512	490	467	440	412	24.2	563	560	557	550	542	533	521	510	495	479	463	35.5
	1	30.00	2.44	3.53	505	501	497	488	475	459	440	420	396	369	24.4	504	502	499	493	486	477	467	455	443	428	413	35.3
	7/8	26.46	2.45	3.51	445	443	438	430	420	407	390	372	350	327	24.5	445	443	440	434	428	421	413	402	390	378	364	35.1
	3/4	22.88	2.47	3.49	385	382	380	373	363	352	338	322	304	284	24.7	384	382	380	376	370	363	355	346	337	325	313	34.9
	5/8	19.22	2.49	3.47	323	321	319	312	305	296	284	272	256	240	24.9	323	322	320	316	310	304	298	291	282	271	261	34.7
	1/2	15.50	2.50	3.45	261	258	257	252	247	239	230	219	207	194	25.0	260	259	258	254	251	246	240	234	227	219	211	34.5
6 x 6	1	22.00	1.80	2.72	366	362	357	344	327	306	281	252	221	221	18.0	367	364	361	353	344	333	320	307	291	274	254	27.2
	7/8	19.46	1.81	2.70	324	320	316	304	289	271	250	225	197	195	18.1	324	322	319	312	304	295	283	271	256	240	223	27.0
	3/4	16.88	1.83	2.68	281	278	274	265	252	236	219	197	172	169	18.3	282	279	276	271	263	255	245	234	222	208	193	26.8
	5/8	14.22	1.84	2.66	237	234	231	223	213	200	185	167	147	142	18.4	237	235	233	228	221	214	206	197	186	174	161	26.6
	1/2	11.50	1.86	2.64	192	190	187	181	172	162	151	136	120	115	18.6	192	190	188	184	179	173	166	158	149	140	129	26.4
	3/8	8.72	1.88	2.62	146	143	141	137	131	123	114	104	92	87	18.8	145	144	142	139	135	131	125	119	113	105	97	26.2
5 x 5	1	18.00	1.48	2.33	297	292	286	270	249	224	194	180			14.8	297	295	291	283	273	261	247	231	213	194	180	23.3
	7/8	15.96	1.49	2.31	263	259	254	240	221	200	173	160			14.9	264	261	258	250	241	230	218	204	188	170	160	23.1
	3/4	13.88	1.51	2.28	230	226	221	219	194	175	153	139			15.1	230	227	224	218	210	199	188	176	162	146	139	22.8
	5/8	11.72	1.52	2.26	194	191	187	177	164	148	130	117			15.2	194	192	189	183	176	168	158	147	135	122	117	22.6
	1/2	9.50	1.54	2.23	157	154	151	144	133	121	107	95			15.4	156	155	153	148	142	135	127	118	108	97	95	22.3
	3/8	7.22	1.56	2.22	119	117	115	109	102	93	82	72			15.6	119	117	116	112	107	102	96	90	82	73	72	22.2
4 x 4	3/4	10.88	1.19	1.88	176	171	166	151	131	110	109				11.9	178	175	171	164	154	143	130	115	109			18.8
	5/8	9.22	1.20	1.86	150	145	140	128	112	93	92				12.0	150	147	144	138	129	120	109	96	92			18.6
	1/2	7.50	1.22	1.83	122	119	115	105	92	77	75				12.2	122	120	118	112	105	97	87	77	75			18.3
	3/8	5.72	1.23	1.81	93	91	88	80	71	59	57				12.3	93	91	89	85	80	73	66	58	57			18.1
	1/4	3.88	1.25	1.79	63	62	60	55	49	41	39				12.5	63	62	61	58	54	50	44	39				17.9
3 1/2 x 3 1/2	3/4	9.38	1.03	1.69	149	144	137	120	97	94					10.3	151	148	144	137	126	114	101	94				16.9
	5/8	7.96	1.04	1.66	127	122	117	102	84	80					10.4	128	125	122	115	106	96	84	80				16.6
	1/2	6.50	1.06	1.64	104	101	96	85	70	65					10.6	104	102	99	94	86	78	67	65				16.4
	3/8	4.96	1.07	1.61	79	77	74	65	54	50					10.7	80	78	76	71	65	58	50	50				16.1
	1/4	3.38	1.09	1.59	54	52	50	45	37	34					10.9	54	53	51	48	44	39	34					15.9
3 x 3	5/8	6.72	0.88	1.46	104	99	92	75	67						8.8	106	103	100	92	82	71	67					14.6
	1/2	5.50	0.90	1.43	86	82	77	63	55						9.0	87	85	82	75	66	57	55					14.3
	3/8	4.22	0.91	1.41	66	63	59	49	42						9.1	66	64	62	57	50	43	42					14.1
	1/4	2.88	0.93	1.38	45	43	41	34	29						9.3	45	44	42	38	34	29						13.8
2 1/2 x 2 1/2	1/2	4.50	0.74	1.24	67	62	56	45							7.4	69	66	63	56	47	45						12.4
	3/8	3.46	0.75	1.21	52	48	43	35							7.5	53	51	48	42	35	35						12.1
	1/4	2.38	0.77	1.19	36	33	30	24							7.7	36	35	33	29	24							11.9

*Values to right of heavy line indicate Max. Loads for $l/r = 120$.

By courtesy of the American Institute of Steel Construction.

STRUCTURAL - STEEL

TABLE A-ALLOWABLE CONCENTRIC LOADS ON STRUTS FORMED BY TWO UNEQUAL ANGLES - LONG LEGS BACK TO BACK.



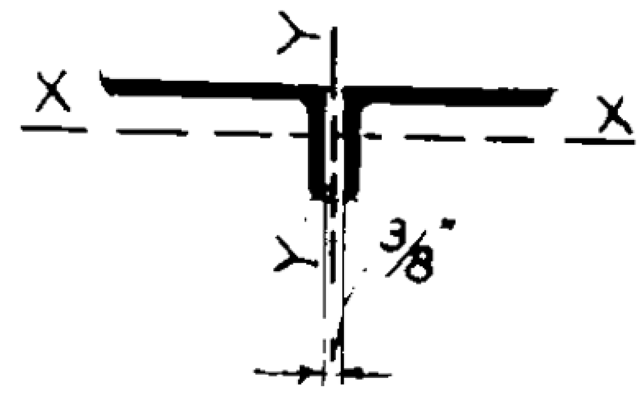
A.I.S.C. CODE-1941 MAXIMUM $l/r = 120$

Size	t	Area	r X-X Axis	r Y-Y Axis	Axis X-X 4	6	8	10	12	14	16	18	20	24	Max. L	Axis Y-Y 4	6	8	10	12	14	16	18	20	22	24	Max. L
					Unbraced Length in Feet - 3/8" Back to Back.																						
8×6	1	26.00	2.49	2.52	437	432	423	413	400	384	368	347	325	274	24.9	437	432	424	414	401	387	370	350	328	305	274	25.2
	7/8	22.96	2.51	2.50	386	381	374	366	354	340	325	308	288	244	25.1	386	382	374	365	354	340	324	307	289	267	243	25.0
	3/4	19.88	2.53	2.48	335	330	325	317	307	295	283	264	251	214	25.3	335	330	324	316	306	294	280	265	248	229	208	24.8
	5/8	16.72	2.54	2.46	282	278	273	267	259	249	238	226	212	181	25.4	282	278	272	265	257	247	235	222	207	192	173	24.6
	1/2	13.50	2.56	2.44	227	224	220	215	209	202	193	183	172	147	25.6	227	224	220	214	207	199	189	178	166	153	138	24.4
8×4	1	22.00	2.52	1.61	370	365	359	350	342	327	312	296	277	235	25.2	364	353	336	315	289	258	223	220				16.1
	7/8	19.46	2.53	1.58	327	323	317	310	302	289	277	262	246	208	25.3	322	311	296	276	252	225	195					15.8
	3/4	16.88	2.55	1.55	284	280	276	269	262	252	241	229	215	183	25.5	279	269	256	238	216	191	169					15.5
	5/8	14.22	2.57	1.53	239	236	233	227	222	213	204	193	182	155	25.7	235	227	215	200	181	159	142					15.3
	1/2	11.50	2.59	1.51	194	191	188	184	179	172	165	157	148	127	25.9	190	183	173	160	145	126	115					15.1
7×4	1	20.00	2.18	1.67	336	329	321	311	298	282	265	245	223	200	21.8	332	322	308	290	268	242	212	200				16.7
	7/8	17.72	2.20	1.64	297	292	285	276	265	251	236	219	199	177	22.0	294	285	272	256	235	211	184	177				16.4
	3/4	15.38	2.22	1.62	258	254	248	240	230	219	205	193	174	154	22.2	255	247	236	220	203	181	157	154				16.2
	5/8	12.96	2.24	1.59	218	214	209	203	195	185	174	162	148	130	22.4	215	208	198	185	169	150	130					15.9
	1/2	10.50	2.25	1.57	176	173	170	164	158	150	141	132	121	105	22.5	174	168	160	149	136	120	105					15.7
	3/8	7.96	2.27	1.55	134	131	128	124	119	114	107	100	92	80	22.7	132	127	120	112	102	90	80					15.5
6×4	7/8	15.96	1.86	1.71	267	260	251	239	224	208	189	167	160		18.6	266	258	247	233	216	197	174	160				17.1
	3/4	13.88	1.88	1.69	232	226	218	209	197	183	166	147	139		18.8	231	224	214	202	187	170	149	139				16.9
	5/8	11.72	1.90	1.66	196	191	185	177	167	155	141	126	117		19.0	195	189	181	170	156	141	123	117				16.6
	1/2	9.50	1.91	1.65	159	155	149	143	135	125	114	103	95		19.1	158	152	146	137	126	113	99	95				16.5
	3/8	7.22	1.93	1.62	120	118	114	109	103	96	88	79	72		19.3	119	116	110	103	95	85	74	72				16.2
5×3½	3/4	11.62	1.55	1.54	192	185	176	164	149	132	116				15.5	192	185	176	163	148	131	116					15.4
	5/8	9.84	1.56	1.51	162	157	149	139	126	111	98				15.6	162	156	148	137	123	107	98					15.1
	1/2	8.00	1.58	1.49	132	128	121	113	103	92	80				15.8	131	126	119	110	99	87	80					14.9
	3/8	6.10	1.60	1.46	101	98	93	87	80	71	61				16.0	100	97	91	84	75	65	61					14.6
4×3½	3/4	10.12	1.20	1.63	164	155	141	123	101	101					120	168	163	155	145	134	120	103	101				16.3
	5/8	8.60	1.22	1.60	140	132	120	106	88	86					12.2	142	138	131	123	117	100	86	86				16.0
	1/2	7.00	1.23	1.58	114	107	98	88	73	70					12.3	116	112	106	100	91	81	70					15.8
	3/8	5.34	1.25	1.56	87	82	75	67	57	53					12.5	89	85	81	76	69	61	53					15.6
4×3	5/8	7.96	1.23	1.36	129	122	112	100	83	80					12.3	131	124	116	105	92	80	NOTE:					13.6
	1/2	6.50	1.25	1.33	106	100	92	82	69	65					12.5	106	101	94	85	74	65	Values to right of					13.3
	3/8	4.96	1.26	1.31	81	76	70	63	53	50					12.6	81	77	71	64	55	50	heavy lines indicate					13.1
	1/4	3.38	1.28	1.29	55	52	48	43	37	34					12.8	55	52	48	43	37	34	Max. Load for $l/r = 120$					12.9
3½×3	5/8	7.34	1.06	1.41	117	108	96	79	73						10.6	120	115	108	99	88	75	73					14.1
	1/2	6.00	1.07	1.38	96	89	79	65	60						10.7	99	94	88	80	72	60						13.8
	3/8	4.60	1.09	1.36	74	68	61	51	46						10.9	76	72	67	61	53	46						13.6
	1/4	3.12	1.11	1.34	50	47	42	35	31						11.1	51	49	45	41	36	31						13.4
3×2½	3/8	3.84	0.93	1.16	60	54	46	38							9.3	62	58	53	45	38							11.6
	1/4	2.62	0.95	1.13	41	37	32	26							9.5	42	40	35	30	26							11.3
2½×2	3/8	3.10	0.77	0.96	47	40	31								7.7	49	44	38	31								9.6
	1/4	2.12	0.78	0.94	32	27	21								7.8	33	30	26	21								9.4

By courtesy of the American Institute of Steel Construction.

STRUCTURAL - STEEL

TABLE A-ALLOWABLE CONCENTRIC LOADS ON STRUTS FORMED BY TWO UNEQUAL ANGLES - SHORT LEGS BACK TO BACK.



A.I.S.C. CODE-1941

MAXIMUM $l/r = 120$

Size	t	Area	r X-X Axis	r Y-Y Axis	Unbraced Length in Feet - 3/8" Back to Back: Axis X-X 4	5	6	8	10	12	14	16	Max. L	Axis Y-Y 6	8	10	12	14	16	18	20	22	24	28	32	36	Max L
8x6	1	26.00	1.73	3.78	432	428	420	404	382	355	323	286	17.3	437	434	429	424	417	410	402	392	381	369	343	312	278	37.8
	7/8	22.96	1.74	3.76	382	378	372	357	335	314	286	253	17.4	386	383	379	374	369	362	354	346	336	325	302	275	243	37.6
	3/4	19.88	1.76	3.73	331	328	322	310	293	274	250	224	17.6	335	332	329	324	319	313	306	298	290	281	260	236	209	37.3
	5/8	16.72	1.77	3.72	278	275	271	261	247	231	211	189	17.7	282	279	276	272	268	263	257	251	244	236	218	198	175	37.2
	1/2	13.50	1.79	3.69	225	222	219	211	200	187	172	154	17.9	227	225	223	220	216	212	207	202	196	190	176	158	140	36.9
8x4	1	22.00	1.03	4.10	351	338	322	282	230	220			10.3	371	369	365	361	356	351	345	338	330	322	302	281	256	41.0
	7/8	19.46	1.04	4.07	310	299	286	251	206	195			10.4	328	326	323	319	315	310	304	298	291	283	267	247	225	40.7
	3/4	16.88	1.05	4.04	270	260	249	218	180	169			10.5	285	283	280	277	273	269	264	258	252	245	230	213	193	40.4
	5/8	14.22	1.07	4.02	228	220	211	187	155	142			10.7	240	238	236	233	230	226	222	217	212	207	194	178	163	40.2
	1/2	11.50	1.08	4.00	185	179	171	151	126	115			10.8	194	192	190	188	186	183	179	175	171	167	156	144	130	40.0
7x4	1	20.00	1.06	3.54	320	300	295	260	216	200			10.6	336	333	329	324	318	312	304	295	286	275	252	226	200	35.4
	7/8	17.72	1.07	3.51	284	274	263	233	194	177			10.7	298	295	292	287	282	276	269	261	253	244	222	199	177	35.1
	3/4	15.38	1.09	3.49	247	239	230	204	171	154			10.9	259	256	253	249	244	239	233	226	219	211	193	171	154	34.9
	5/8	12.96	1.10	3.47	208	202	194	173	146	130			11.0	218	216	213	210	206	202	197	191	184	177	161	143	130	34.7
	1/2	10.50	1.11	3.45	169	164	157	141	118	105			11.1	176	175	173	170	167	163	159	154	149	143	131	115	105	34.5
	3/8	7.96	1.13	3.42	128	124	120	107	92	80			11.3	134	132	130	128	126	123	120	116	112	108	98	87	80	34.2
6x4	7/8	15.96	1.11	2.97	257	248	238	214	181	160			11.1	267	264	260	254	246	238	230	220	210	199	173	160		29.7
	3/4	13.88	1.12	2.95	224	216	208	187	159	139			11.2	232	229	225	220	214	208	200	192	182	172	148	139		29.5
	5/8	11.72	1.13	2.92	189	183	177	158	136	117			11.3	196	193	190	186	181	175	168	161	153	144	124	117		29.2
	1/2	9.50	1.15	2.90	153	149	143	129	110	95			11.5	158	156	153	150	146	141	136	130	123	116	99	95		29.0
	3/8	7.22	1.17	2.87	117	113	109	99	86	72			11.7	121	118	116	114	111	107	103	98	93	88	75	72		28.7
5x3½	3/4	11.62	0.98	2.48	184	177	167	143	116				9.8	193	189	184	179	172	164	155	145	133	122	116			24.8
	5/8	9.84	0.99	2.45	155	149	142	122	98				9.9	163	160	155	150	144	138	130	121	112	101	98			24.5
	1/2	8.00	1.01	2.43	127	122	116	101	82	80			10.1	132	130	126	122	117	112	105	98	91	82	80			24.3
	3/8	6.10	1.02	2.40	97	94	89	78	63	61			10.2	101	99	96	93	89	85	80	74	68	61	61			24.0
4x3½	3/4	10.12	1.01	1.94	161	155	147	127	104	101			10.1	165	160	153	145	135	124	111	101						19.4
	5/8	8.60	1.03	1.91	137	132	126	110	90	86			10.3	140	135	130	122	114	104	93	86						19.1
	1/2	7.00	1.04	1.89	112	108	103	90	74	70			10.4	114	110	105	99	92	84	75	70						18.9
	3/8	5.34	1.06	1.88	86	83	79	70	58	53			10.6	87	84	80	75	70	64	57	53						18.8
4x3	5/8	7.96	0.85	1.99	123	116	108	86	80				8.5	130	126	121	115	108	100	90	80						19.9
	1/2	6.50	0.86	1.96	101	95	89	71	65				8.6	106	103	99	94	88	81	72	65						19.6
	3/8	4.96	0.88	1.94	77	73	67	56	50				8.8	81	78	75	71	66	61	55	50						19.4
	1/4	3.38	0.90	1.92	53	50	47	39	34				9.0	55	53	51	48	45	41	37	34						19.2
3½x3	5/8	7.34	0.87	1.72	114	108	100	82	73				8.7	118	113	107	100	91	80	73							17.2
	1/2	6.00	0.88	1.70	94	89	83	67	60				8.8	97	93	88	81	74	65	60							17.0
	3/8	4.60	0.90	1.67	72	68	64	53	46				9.0	74	71	67	62	56	49	46							16.7
	1/4	3.12	0.91	1.65	49	47	44	36	31				9.1	50	48	45	41	37	33	31							16.5
3x2½	3/8	3.84	0.74	1.48	57	53	48	38					7.4	61	57	53	48	41	38								14.8
	1/4	2.62	0.75	1.45	40	37	33	26					7.5	41	39	36	32	28	26								14.5
2½x2	3/8	3.10	0.58	1.27	42	37	31						5.8	48	44	40	34	31									12.7
	1/4	2.12	0.59	1.25	29	25	21						5.9	33	30	27	22	21									12.5

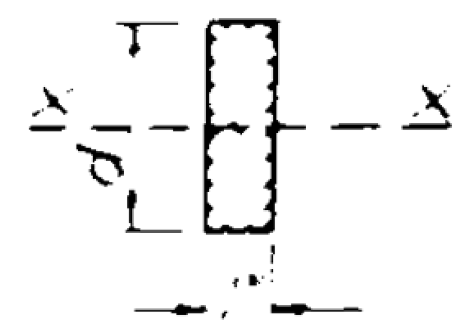
NOTE: Values to right of heavy lines indicate Max. Load for $l/r = 120$

By courtesy of American Institute of Steel Construction.

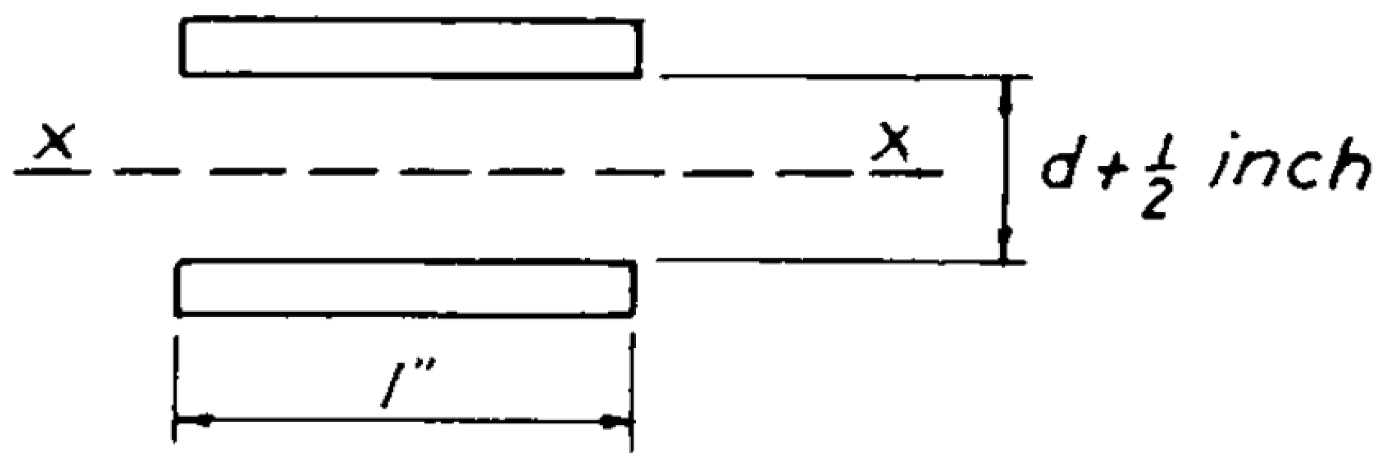
STRUCTURAL — STEEL

TABLE A - MOMENTS OF INERTIA ABOUT AXIS X-X.

ONE PLATE 1 INCH WIDE



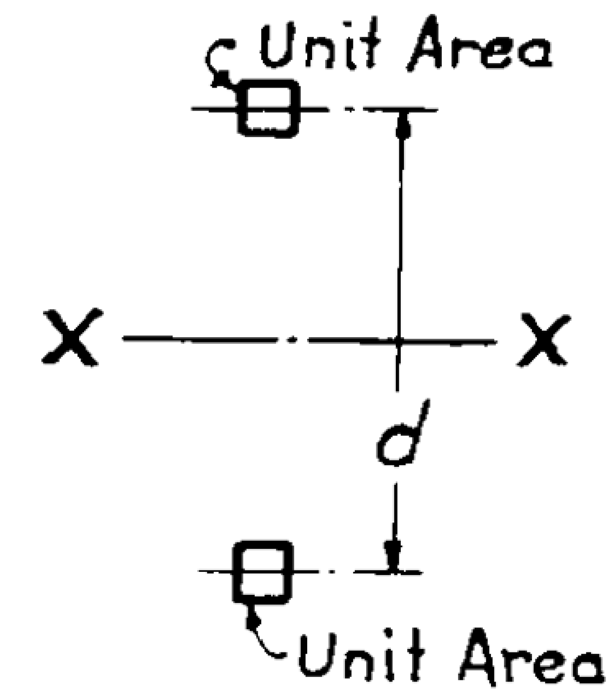
TWO PLATES 1 INCH WIDE



DEPTH OF WEB PLATE d-inches	THICKNESS 1"	THICKNESS OF FLANGE PLATES IN INCHES 3/8"	7/16"	1/2"	9/16"	5/8"	11/16"	3/4"	13/16"	7/8"	15/16"	1"	1 1/8"	1 1/4"
24	1152.0	116.0	136.0	156.3	176.7	197.3	218.1	239.2	260.4	281.8	303.5	325.3	369.6	414.7
26	1464.7	135.4	158.7	182.3	206.0	230.0	254.1	278.5	303.1	328.0	353.0	378.3	429.5	481.6
28	1829.3	156.3	183.2	210.3	237.6	265.1	292.9	320.9	349.2	377.6	406.3	435.3	493.9	553.5
30	2250.0	178.7	209.4	240.3	271.4	302.8	334.4	366.3	398.4	430.8	463.4	496.3	562.8	630.4
32	2730.7	202.7	237.3	272.3	307.5	342.9	378.7	414.7	450.9	487.4	524.2	561.3	636.2	712.2
34	3275.3	228.1	267.0	306.3	345.8	385.6	425.7	466.0	506.7	547.6	588.8	630.3	714.1	799.1
36	3888.0	255.0	298.5	342.3	386.4	430.7	475.4	520.4	565.7	611.2	657.1	703.3	796.5	891.0
38	4572.7	283.4	331.7	380.3	429.2	478.4	527.9	577.8	627.9	678.4	729.2	780.3	883.4	987.9
40	5333.3	313.3	366.6	420.3	474.3	528.6	583.2	638.2	693.4	749.1	805.0	861.3	974.8	1089.7
42	6174.0	344.7	403.3	462.3	521.6	581.2	641.2	701.5	762.2	823.2	884.6	946.3	1070.8	1196.6
44	7098.7	377.6	441.7	506.3	571.1	636.4	702.0	767.9	834.2	900.9	967.9	1035.3	1171.2	1308.5
46	8111.0	412.0	481.9	552.3	623.0	694.0	765.5	837.3	909.5	982.0	1055.0	1128.3	1276.1	1425.4
48	9216.	447.9	523.9	600.3	677.0	754.2	831.7	909.7	988.0	1066.7	1145.8	1225.3	1385.5	1547.2
50	10417.	485.3	567.6	650.3	733.4	816.8	900.7	985.0	1069.7	1154.8	1240.4	1326.3	1499.4	1674.1
52	11717	524.2	613.0	702.3	791.9	882.0	972.5	1063.4	1154.7	1246.5	1338.7	1431.3	1617.8	1806.0
54	13122.	564.6	660.2	756.3	852.7	949.7	1047.0	1144.8	1243.0	1341.7	1440.8	1540.3	1740.7	1942.9
56	14635	606.5	709.2	812.3	915.8	1019.8	1124.3	1229.2	1334.5	1440.3	1546.6	1653.3	1868.1	2084.7
58	16259.	649.9	759.9	870.3	981.1	1092.5	1204.3	1316.5	1429.3	1542.5	1656.1	1770.3	2000.0	2231.6
60	18000.	694.8	812.3	930.3	1048.7	1167.6	1287.0	1406.9	1527.3	1648.1	1769.5	1891.3	2136.4	2383.5
62	19861.	741.2	866.5	992.3	1118.5	1245.3	1372.5	1500.3	1628.5	1757.3	1886.5	2016.3	2277.3	2540.4
64	21845	789.1	922.4	1056.3	1190.6	1325.4	1460.8	1596.7	1733.0	1869.9	2007.4	2145.3	2422.7	2702.2
66	23958.	838.6	980.1	1122.3	1264.9	1408.1	1551.8	1696.0	1840.8	1986.1	2131.9	2278.3	2572.6	2869.1
68	26203.	889.5	1039.6	1190.3	1341.5	1493.2	1645.6	1798.4	1951.8	2105.7	2260.2	2415.3	2727.0	3041.0
70	28583	941.9	1100.8	1260.3	1420.3	1580.9	1742.1	1903.8	2066.1	2228.9	2392.3	2556.3	2885.9	3217.9
72	31104	995.8	1163.7	1332.3	1501.4	1671.1	1841.3	2012.2	2183.6	2355.5	2528.1	2701.3	3049.3	3399.7
74	33769.	1051.2	1228.4	1406.3	1584.7	1763.7	1943.3	2123.5	2304.3	2485.7	2667.7	2850.3	3217.3	3586.6
76	36581.	1108.1	1294.9	1482.3	1670.3	1858.9	2048.1	2237.9	2428.3	2619.4	2811.0	3003.3	3389.7	3778.5
78	39546.	1166.5	1363.1	1560.3	1758.1	1956.5	2155.6	2355.3	2555.6	2756.5	2958.1	3160.3	3566.6	3975.4
80	42667.	1226.4	1433.0	1640.3	1848.2	2056.7	2265.9	2475.7	2686.1	2897.2	3108.9	3321.3	3748.0	4177.2
82	45947.	1287.8	1504.7	1722.3	1940.5	2159.3	2378.9	2599.0	2819.9	3041.3	3263.5	3486.3	3933.9	4384.1
84	49392.	1350.7	1578.1	1806.3	2035.0	2264.5	2494.6	2725.4	2956.9	3189.0	3421.8	3655.3	4124.3	4596.0

STRUCTURAL — STEEL

MOMENT OF INERTIA OF A PAIR OF UNIT AREAS ABOUT AXIS X-X



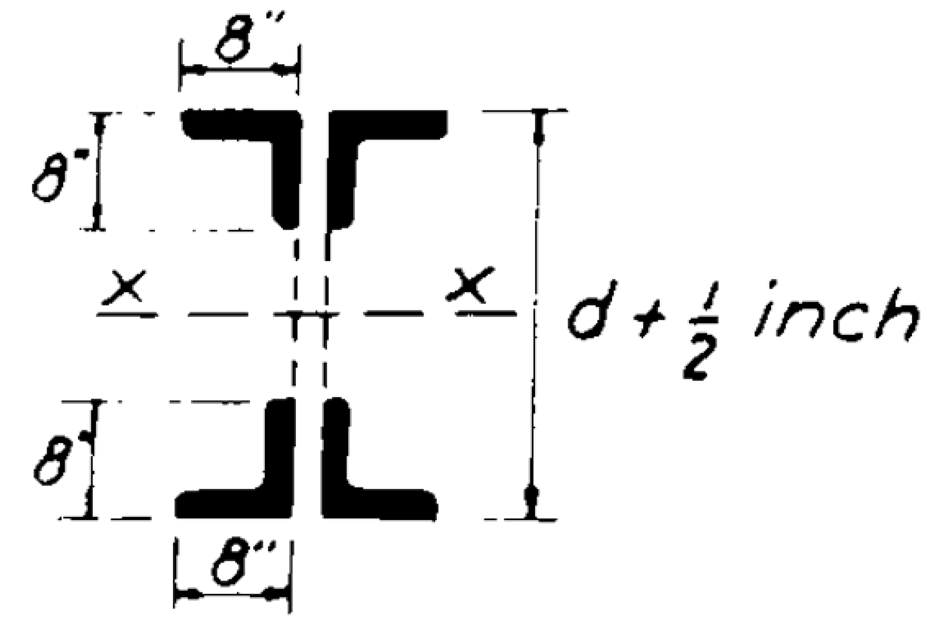
d	.0	.2	.4	.6	.8
10	50	52	54	56	58
11	61	63	65	67	70
12	72	74	77	79	82
13	85	87	90	92	95
14	98	101	104	107	110
15	113	116	119	122	125
16	128	131	134	138	141
17	145	148	151	155	158
18	162	166	169	173	177
19	181	184	188	192	196
20	200	204	208	212	216
21	221	225	229	233	238
22	242	246	251	255	260
23	265	269	274	278	283
24	288	293	298	303	308
25	313	318	323	328	333
26	338	343	348	354	359
27	365	370	375	381	386
28	392	398	403	409	415
29	421	426	432	438	444
30	450	456	462	468	474
32	512	518	525	531	538
34	578	585	592	598	606
36	648	655	662	670	677
38	722	730	737	745	753
40	800	808	816	824	832
42	882	890	899	907	916
44	968	977	986	995	1004
46	1058	1067	1076	1086	1095
48	1152	1162	1171	1181	1191
50	1250	1260	1270	1280	1290
52	1352	1362	1373	1383	1394
54	1458	1469	1480	1491	1502
56	1568	1579	1590	1602	1613

d	.0	.2	.4	.6	.8
58	1682	1694	1705	1717	1729
60	1800	1812	1824	1836	1848
62	1922	1934	1947	1959	1972
64	2048	2061	2074	2087	2100
66	2178	2191	2204	2218	2231
68	2312	2326	2339	2353	2367
70	2450	2464	2478	2492	2506
72	2592	2606	2621	2635	2650
74	2738	2753	2768	2783	2798
76	2888	2903	2918	2934	2949
78	3042	3058	3073	3089	3105
80	3200	3216	3232	3248	3264
82	3362	3378	3395	3411	3428
84	3528	3545	3562	3579	3596
86	3698	3715	3732	3750	3767
88	3872	3890	3907	3925	3943
90	4050	4068	4086	4104	4122
92	4232	4250	4269	4287	4306
94	4418	4437	4456	4475	4494
96	4608	4627	4646	4666	4685
98	4802	4822	4841	4861	4881
100	5000	5020	5040	5060	5080
102	5202	5222	5243	5263	5284
104	5408	5429	5450	5471	5492
106	5618	5639	5660	5682	5703
108	5832	5854	5875	5897	5919
110	6050	6072	6094	6116	6138
112	6272	6294	6317	6339	6362
114	6498	6521	6544	6567	6590
116	6728	6751	6774	6798	6821
118	6962	6986	7009	7033	7057
120	7200	7224	7248	7272	7296
122	7442	7466	7491	7515	7540
124	7688	7713	7738	7763	7788

STRUCTURAL — STEEL

TABLE A - MOMENTS OF INERTIA OF FOUR ANGLES.

8 x 8 ANGLES

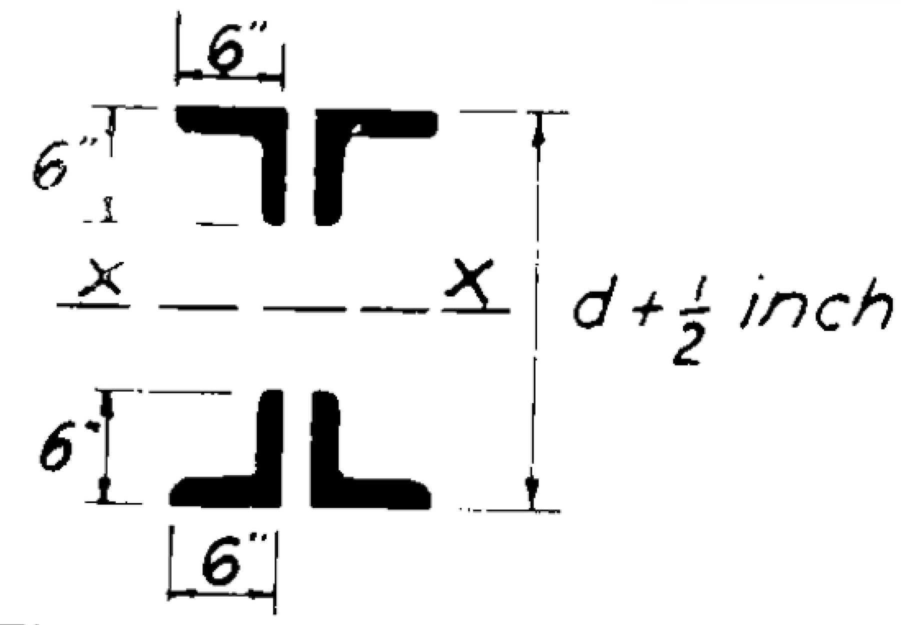


THICKNESS	1/2"	9/16"	5/8"	11/16"	3/4"	13/16"	7/8"	15/16"	1"	1 1/16"	1 1/8"
AREA 4 Ls	31.00	34.72	38.44	42.12	45.76	49.36	52.92	56.48	60.00	63.48	66.92
d IN INCHES	MOMENTS OF INERTIA ABOUT AXIS X-X IN INCHES⁴ FOR VARIOUS DISTANCES BACK TO BACK OF ANGLES										
24	3332	3716	4097	4471	4828	5186	5536	5884	6213	6646	6871
26	3987	4448	4906	5355	5786	6217	6640	7060	7458	7861	8255
28	4703	5249	5792	6324	6835	7348	7850	8349	8824	9303	9773
30	5482	6120	6754	7377	7977	8577	9166	9751	10310	10872	11425
32	6323	7060	7794	8514	9209	9904	10587	11266	11915	12569	13210
34	7225	8070	8910	9736	10534	11331	12114	12893	13641	14392	15129
36	8190	9149	10103	11041	11950	12856	13748	14634	15486	16342	17183
38	9217	10298	11373	12431	13457	14480	15487	16488	17452	18419	19369
40	10306	11516	12720	13905	15056	16203	17331	18454	19538	20623	21690
42	11456	12803	14144	15464	16746	18024	19282	20534	21743	22954	24145
44	12669	14160	15645	17107	18528	19944	21338	22726	24069	25412	26733
46	13944	15586	17222	18833	20401	21963	23501	25032	26514	27997	29456
48	15280	17082	18877	20645	22366	24081	25769	27450	29080	30709	32312
50	16679	18647	20608	22540	24423	26291	28143	29982	31766	33548	35302
52	18140	20282	22416	24520	26571	28612	30623	32626	34571	36513	38426
54	19663	21986	24301	26584	28810	31026	33208	35384	37497	39606	41684
56	21247	23759	26263	28732	31141	33538	35900	38254	40542	42826	45075
58	22894	25602	28302	30964	33564	36149	38697	41237	43708	46172	48601
60	24603	27515	30418	33281	36078	38859	41600	44333	46994	49646	52260
62	26376	29497	32610	35681	38683	41668	44609	47543	50399	53247	56053
64	28206	31548	34880	38167	41381	44575	47724	50865	53925	56974	59980
66	30101	33669	37226	40736	44169	47581	50945	54300	57570	60829	64040
68	32058	35859	39650	43389	47049	50686	54272	57848	61336	64810	68235
70	34076	38118	42150	46127	50021	53889	57704	61509	65222	68919	72563
72	36157	40447	44727	48949	53084	57191	61242	65283	69227	73154	77025
74	38300	42846	47381	51856	56239	60592	64886	69170	73353	77516	81621
76	40505	45314	50111	54846	59485	64092	68636	73170	77598	82006	86351
78	42771	47851	52919	57921	62823	67690	72492	77283	81964	86622	91215
80	45100	50458	55804	61080	66252	71387	76453	81509	86450	91365	96213
82	47491	53134	58765	64323	69773	75183	80521	85847	91055	96235	101344
84	49943	55880	61803	67651	73385	79077	84694	90299	95781	101233	106609

STRUCTURAL — STEEL

TABLE A - MOMENTS OF INERTIA OF FOUR ANGLES.

6 x 6 ANGLES

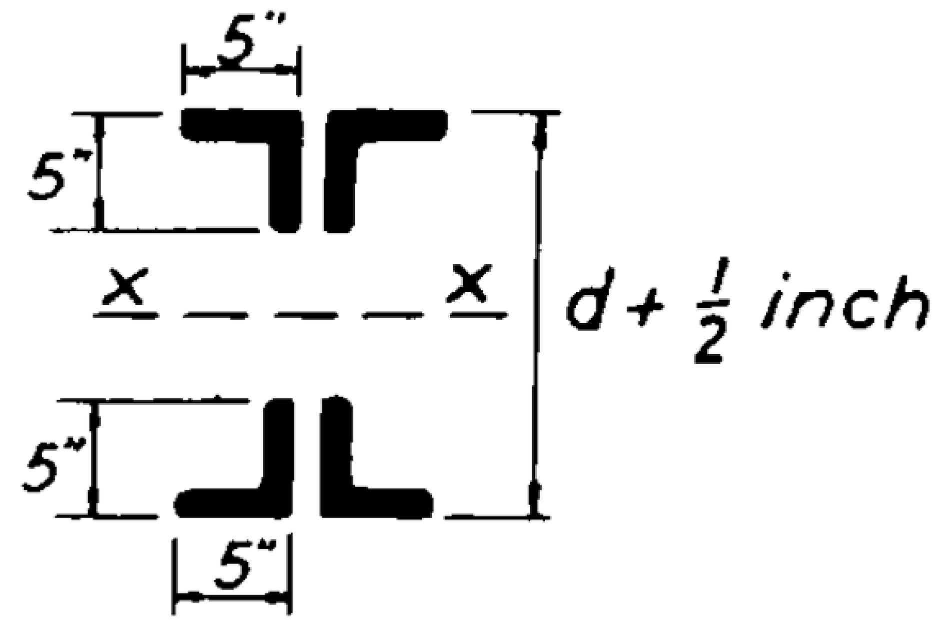


THICKNESS	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1"
AREA 4 Ls	17.4	20.2	23.0	25.7	28.4	31.1	33.8	36.4	38.9	41.5	44.0
d IN INCHES	MOMENTS OF INERTIA ABOUT AXIS X-X IN INCHES4 FOR VARIOUS DISTANCES BACK TO BACK OF ANGLES										
24	2025	2341	2649	2946	3244	3536	3813	4091	4362	4630	4892
26	2412	2790	3159	3513	3871	4220	4554	4887	5212	5535	5850
28	2835	3279	3714	4133	4555	4967	5362	5756	6141	6523	6896
30	3292	3809	4315	4804	5295	5776	6238	6698	7147	7594	8031
32	3784	4379	4962	5526	6093	6648	7181	7712	8232	8748	9253
34	4311	4990	5655	6299	6947	7581	8192	8799	9394	9985	10563
36	4873	5641	6395	7125	7858	8577	9270	9959	10634	11305	11962
38	5470	6333	7180	8001	8826	9635	10416	11192	11952	12708	13448
40	6102	7065	8011	8929	9851	10756	11629	12497	13347	14194	15022
42	6768	7838	8888	9909	10933	11938	12910	13875	14821	15762	16685
44	7470	8651	9812	10939	12072	13183	14259	15326	16372	17414	18435
46	8206	9505	10781	12022	13268	14490	15675	16850	18001	19149	20273
48	8977	10399	11796	13155	14520	15859	17158	18446	19709	20966	22200
50	9783	11334	12857	14341	15829	17291	18709	20115	21493	22867	24214
52	10624	12309	13964	15577	17196	18785	20327	21856	23356	24850	26316
54	11500	13325	15118	16865	18619	20341	22013	23671	25297	26917	28507
56	12411	14381	16317	18205	20099	21959	23767	25558	27315	29066	30785
58	13356	15478	17562	19596	21636	23639	25588	27518	29411	31299	33151
60	14337	16615	18853	21038	23230	25382	27476	29550	31585	33614	35605
62	15352	17792	20191	22532	24880	27187	29432	31655	33837	36013	38148
64	16402	19010	21574	24077	26588	29054	31456	33833	36167	38494	40778
66	17488	20269	23003	25673	28352	30984	33547	36084	38575	41058	43496
68	18608	21568	24478	27322	31073	32975	35706	38407	41060	43706	46303
70	19762	22907	25999	29022	32052	35029	37932	40803	43623	46436	49197
72	20952	24287	27567	30773	33987	37145	40225	43272	46264	49249	52179
74	22177	25708	29180	32575	35979	39324	42587	45814	48983	52145	55250
76	23436	27169	30839	34429	38027	41564	45015	48428	51780	55124	58408
78	24731	28670	32544	36334	40133	43867	47512	51115	54655	58186	61654
80	26060	30212	34295	38291	42296	46232	50075	53875	57607	61331	64989
82	27424	31794	36093	40299	44515	48660	52707	56707	60638	64559	68411
84	28823	33417	37936	42359	46792	51149	55405	59612	63746	67870	71921

STRUCTURAL — STEEL

TABLE A — MOMENTS OF INERTIA OF FOUR ANGLES.

5 X 5 ANGLES

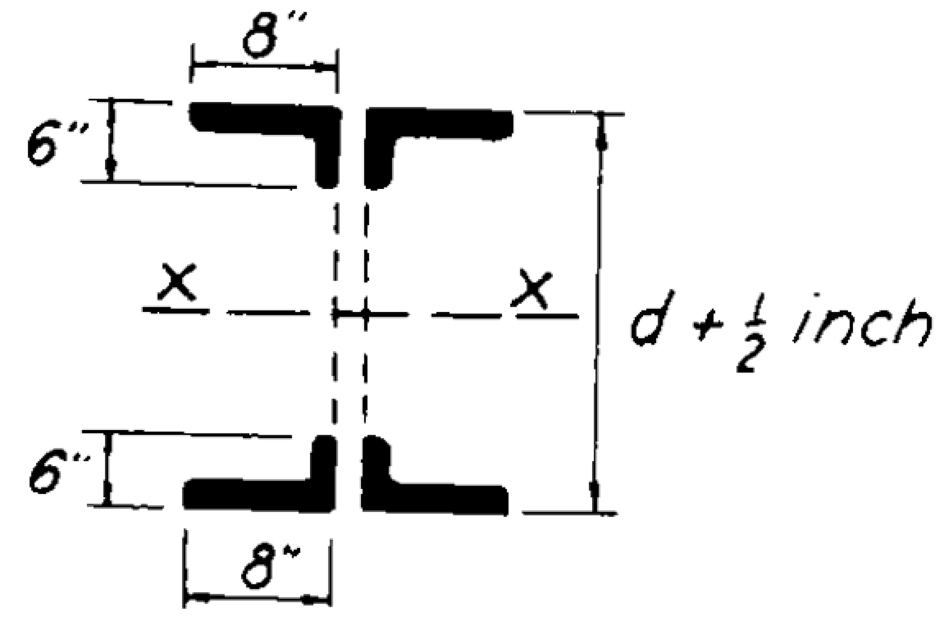


THICKNESS	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1"
AREA 4 Ls	14.44	16.72	19.00	21.24	23.44	25.60	27.76	29.88	31.92	34.00	36.00
d IN INCHES	MOMENTS OF INERTIA ABOUT AXIS X-X IN INCHES4 FOR VARIOUS DISTANCES BACK TO BACK OF ANGLES										
24	1738	2002	2269	2518	2769	3017	3263	3490	3721	3939	4154
26	2066	2381	2700	2997	3296	3593	3888	4160	4437	4697	4957
28	2423	2793	3168	3520	3870	4221	4568	4890	5216	5524	5830
30	2809	3239	3674	4081	4491	4899	5304	5679	6060	6424	6776
32	3224	3718	4218	4687	5159	5624	6095	6528	6967	7382	7794
34	3667	4230	4800	5336	5873	6409	6942	7437	7939	8413	8884
36	4140	4776	5420	6026	6635	7241	7844	8406	8974	9512	10046
38	4641	5355	6078	6759	7443	8125	8802	9434	10074	10679	11280
40	5171	5968	6775	7535	8298	9059	9816	10523	11237	11914	12586
42	5730	6614	7509	8353	9200	10045	10885	11671	12465	13217	13964
44	6318	7293	8281	9213	10154	11081	12010	12879	13756	14587	15414
46	6935	8006	9101	10116	11144	12169	13190	14194	15112	16056	16936
48	7583	8752	9939	11061	12186	13309	14426	15474	16541	17533	18531
50	8256	9531	10825	12048	13275	14499	15717	16862	18015	19108	20197
52	3959	10344	11750	13078	14401	15737	17065	18309	19562	20751	21931
54	9692	11191	12712	14151	15594	17033	18468	19816	21174	22462	23745
56	10453	12070	13712	15275	16823	18377	19926	21382	22850	24241	25627
58	11243	12984	14750	16422	18099	19773	21440	23017	24589	26088	27581
60	12062	13930	15826	17622	19422	21219	23009	24695	26392	28002	29607
62	12910	14910	16940	18864	20792	22714	24635	26441	28260	29985	31705
64	3787	15923	18093	20148	22199	24265	26315	28247	30191	32036	33875
66	14692	16970	19283	21475	23672	25865	28052	30113	32187	34155	36107
68	15627	18050	20511	22844	25183	27517	29844	32039	34246	36343	38431
70	16590	19163	21777	24275	26740	29219	31691	34024	36370	38597	40817
72	17583	20311	23081	25709	28343	30973	33595	36069	38557	40920	43275
74	18604	21491	24423	27206	29994	32777	35553	38174	40809	43311	47806
76	19654	22705	25804	28744	31692	34633	37568	40339	43125	45769	48408
78	20733	23952	27222	30325	33436	36541	39638	42564	45504	48296	51082
80	21841	25233	28678	31949	35227	38499	41763	44848	47948	50891	53828
82	22978	26547	30172	33615	37065	40509	43945	47192	50455	53554	56646
84	24143	27894	31704	35323	38949	42569	46181	49596	53027	56285	59536

STRUCTURAL — STEEL

TABLE A – MOMENTS OF INERTIA OF FOUR ANGLES.

8 x 6 ANGLES

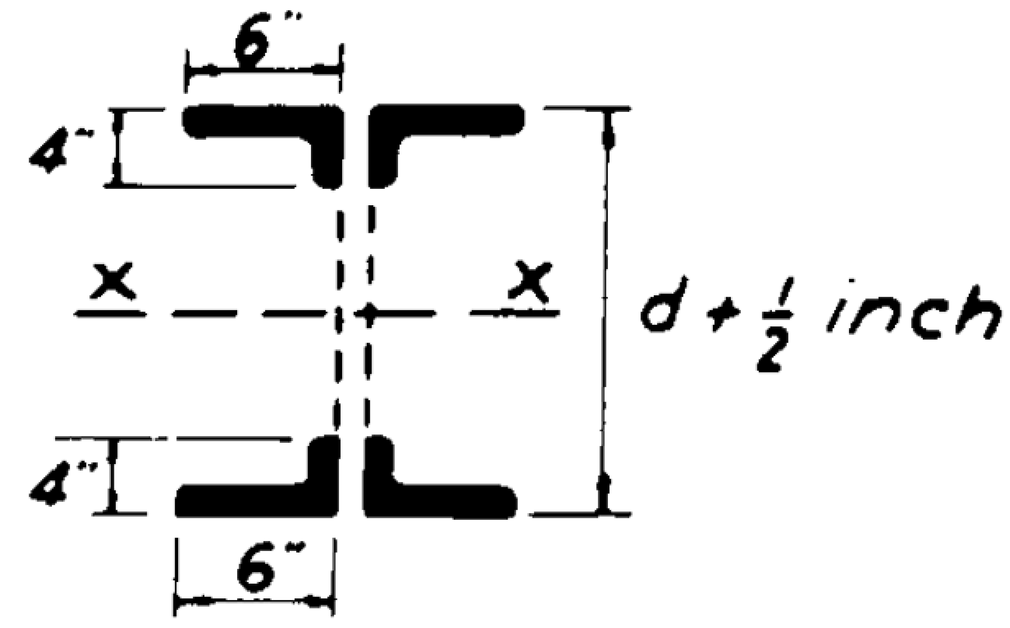


THICKNESS	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1"
AREA 4 L^S	23.72	27.00	30.24	33.44	36.60	39.76	42.88	45.92	49.00	52.00
d IN INCHES	MOMENTS OF INERTIA ABOUT AXIS X-X IN INCHES4 FOR VARIOUS DISTANCES BACK TO BACK OF ANGLES									
24	2844	3224	3591	3955	4312	4667	5004	5338	5674	5998
26	3380	3833	4271	4706	5133	5556	5961	6361	6764	7152
28	3963	4497	5012	5524	6027	6526	7004	7476	7951	8411
30	4594	5214	5813	6409	6994	7575	8133	8683	9237	9773
32	5273	5985	6675	7361	8034	8703	9347	9982	10621	11239
34	5999	6810	7598	8379	9147	9911	10647	11372	12103	12810
36	6772	7689	8580	9465	10334	11198	12033	12854	13682	14484
38	7593	8622	9624	10617	11594	12565	13505	14428	15360	16263
40	8461	9609	10727	11836	12927	14012	15062	16094	17136	18145
42	9376	10650	11892	13123	14333	15538	16705	17852	19010	20131
44	10339	11746	13116	14476	15812	17143	18434	19702	20981	22222
46	11350	12895	14402	15895	17365	18828	20249	21643	23051	24416
48	12408	14098	15747	17382	18990	20593	22149	23677	25219	26715
50	13513	15355	17153	18936	20689	22437	24135	25082	27485	29117
52	14666	16666	18620	20556	22462	24360	26207	28019	29848	31623
54	15866	18031	20147	22244	24307	26364	28365	30328	32310	34234
56	17114	19450	21735	23998	26226	28446	30608	32728	34870	36948
58	18409	20923	23383	25819	28217	30608	32938	35221	37528	39767
60	19751	22450	25091	27707	30282	32850	35353	37805	40284	42689
62	21141	24032	26860	29662	32420	35171	37853	40482	43137	45715
64	22579	25667	28690	31684	34632	37572	40440	43250	46089	48846
66	24064	27356	30580	33772	36916	40052	43112	46110	49139	52080
68	25596	29099	32530	35928	39274	42612	45870	49061	52287	55419
70	27176	30896	34541	38150	41705	45251	48714	52105	55532	58861
72	28803	32747	36613	40440	44209	47970	51644	55240	58876	62407
74	30478	34652	38745	42796	46787	50768	54659	58468	62318	66058
76	32200	36611	40937	45219	49437	53646	57760	61787	65858	69812
78	33969	38625	43190	47709	52161	56603	60947	65198	69495	73671
80	35786	40692	45503	50266	54958	59640	64220	68700	73231	77633
82	37651	42813	47877	52889	57828	62757	67578	72295	77065	81699
84	39562	44988	50312	55800	60771	65953	71022	75981	80997	85870

STRUCTURAL — STEEL

TABLE A - MOMENTS OF INERTIA OF FOUR ANGLES.

6 x 4 ANGLES

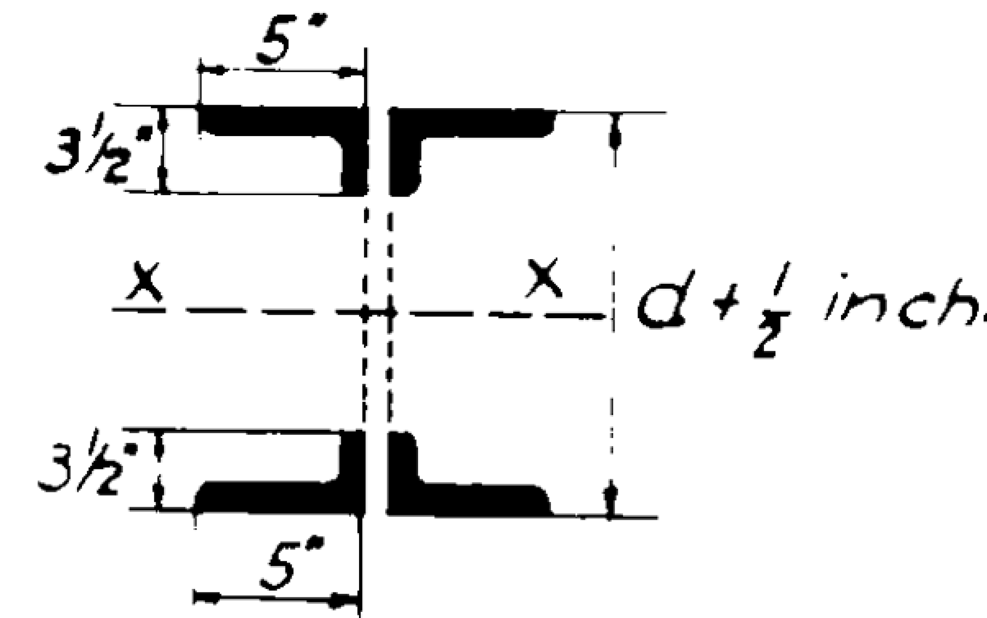


THICKNESS	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8
AREA 4 Ls	14.44	16.72	19.00	21.24	23.44	25.60	27.76	29.88	31.92
d IN INCHES	MOMENTS OF INERTIA ABOUT AXIS X-X IN INCHES⁴ FOR VARIOUS DISTANCES BACK TO BACK OF ANGLES								
24	1867	2154	2434	2711	2981	3238	3498	3752	3993
26	2208	2548	2881	3210	3530	3837	4146	4448	4736
28	2578	2976	3366	3751	4127	4486	4850	5204	5542
30	2977	3437	3889	4335	4770	5187	5609	6020	6412
32	3404	3931	4450	4961	5460	5939	6423	6895	7346
34	3861	4459	5048	5629	6197	6743	7293	7830	8344
36	4346	5021	5685	6341	6981	7597	8219	8825	9406
38	4861	5616	6360	7094	7811	8503	9200	9880	10531
40	5404	6244	7073	7890	8689	9460	10236	10995	11720
42	5976	6906	7824	8729	9613	10468	11328	12169	12974
44	6577	7601	8613	9610	10585	11527	12476	13403	14291
46	7207	8330	9440	10533	11603	12638	13679	14697	15671
48	7866	9092	10305	11499	12668	13800	14938	16050	17116
50	8553	9887	11207	12508	13780	15012	16252	17464	18625
52	9270	10716	12148	13559	14939	16277	17622	18937	20197
54	10015	11579	13127	14652	16145	17592	19047	20470	21833
56	10789	12475	14144	15788	17397	18958	20527	22062	23533
58	11593	13404	15199	16967	18697	20376	22064	23715	25297
60	12425	14367	16292	18187	20043	21845	23655	25427	27125
62	13286	15363	17423	19451	21437	23365	25303	27199	29017
64	14175	16392	18592	20757	22877	24937	27006	29030	30972
66	15094	17455	19799	22105	24364	26559	28764	30922	32991
68	16042	18552	21043	23496	25898	28233	30578	32873	35074
70	17018	19682	22326	24929	27478	29958	32447	34885	37221
72	18023	20845	23647	26405	29106	31734	34372	36955	39432
74	19057	22042	25006	27923	30781	33561	36352	39086	41707
76	20121	23272	26403	29484	32502	35440	38388	41276	44045
78	21212	24536	27838	31087	34270	37370	40480	43526	46447
80	22333	25833	29311	32733	36086	39350	42627	45836	48914
82	23483	27164	30822	34421	37948	41383	44829	48205	51444
84	24662	28528	32370	36151	39857	43466	47087	50634	54037

STRUCTURAL - STEEL

TABLE A - MOMENTS OF INERTIA OF FOUR ANGLES.

5 x 3½ ANGLES
LONG LEGS OUT

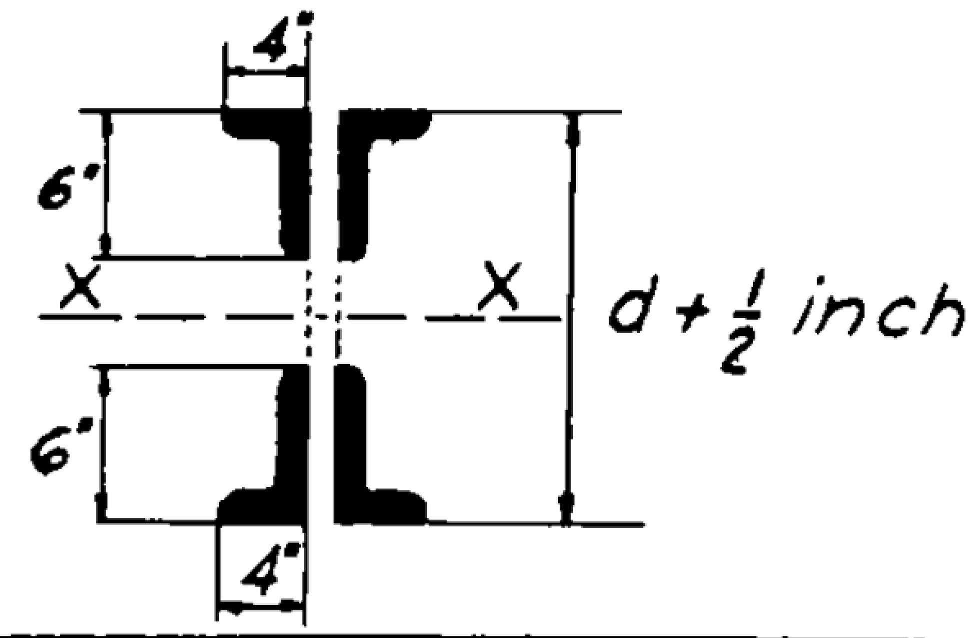


THICKNESS	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4
AREA 4 Ls	10.24	12.20	14.12	16.00	17.88	19.68	21.48	23.24
d IN INCHES	MOMENTS OF INERTIA ABOUT AXIS X-X IN INCHES^4 FOR VARIOUS DISTANCES BACK TO BACK OF ANGLES							
7	98	115	131	145	160	174	187	198
8	130	153	175	195	215	233	252	268
9	167	197	226	252	279	303	328	349
10	210	248	284	318	351	382	414	442
12	311	367	422	472	524	571	620	663
14	432	511	587	659	732	800	868	930
16	573	679	781	878	976	1067	1159	1244
18	735	872	1004	1129	1256	1374	1493	1604
20	918	1088	1254	1412	1571	1721	1871	2011
22	1121	1330	1533	1727	1922	2107	2291	2464
24	1344	1595	1840	2074	2309	2532	2754	2964
26	1588	1886	2175	2453	2732	2997	3260	3510
28	1852	2200	2539	2864	3190	3501	3809	4102
30	2137	2539	2930	3306	3684	4044	4401	4741
32	2443	2902	3350	3781	4214	4626	5036	5427
34	2768	3290	3798	4288	4780	5248	5714	6159
36	3115	3702	4275	4827	5381	5909	6435	6938
38	3482	4139	4779	5398	6019	6610	7199	7763
40	3869	4600	5312	6001	6692	7350	8005	8634
42	4277	5085	5873	6636	7400	8129	8855	9552
44	4705	5595	6463	7303	8145	8948	9748	10517
46	5153	6129	7080	8001	8925	9806	10683	11527
48	5623	6687	7726	8732	9741	10703	11662	12585
50	6112	7270	8400	9495	10593	11640	12684	13688
52	6623	7878	9103	10290	11481	12616	13748	14839
54	7153	8509	9833	11117	12404	13632	14856	16035
56	7704	9165	10592	11976	13363	14687	16006	17279
58	8276	9846	11379	12867	14358	15781	17199	18569
60	8868	10551	12194	13790	15389	16914	18436	19905
62	9481	11280	13038	14744	16455	18087	19715	21288

STRUCTURAL - STEEL

TABLE A - MOMENTS OF INERTIA OF FOUR ANGLES.

6 x 4 ANGLES

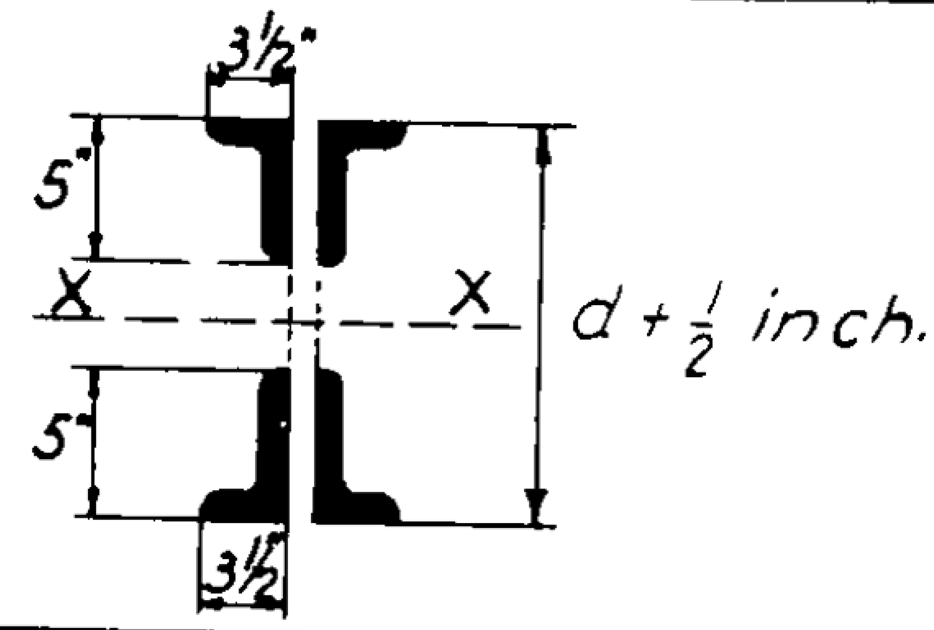


THICKNESS	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8
AREA 4 Ls	14.44	16.72	19.00	21.24	23.44	25.60	27.76	29.88	31.92
d IN INCHES	MOMENTS OF INERTIA ABOUT AXIS X-X IN INCHES⁴ FOR VARIOUS DISTANCES BACK TO BACK OF ANGLES								
24	1589	1832	2070	2304	2533	2749	2969	3183	3387
26	1901	2193	2479	2760	3035	3297	3562	3819	4066
28	2242	2587	2925	3259	3585	3895	4210	4516	4808
30	2612	3015	3410	3800	4181	4545	4913	5272	5614
32	3011	3476	3933	4384	4824	5246	5672	6087	6484
34	3439	3971	4494	5010	5514	5998	6486	6963	7418
36	3895	4499	5093	5679	6251	6801	7356	7898	8416
38	4381	5060	5730	6390	7035	7656	8282	8893	9478
40	4895	5655	6405	7143	7866	8562	9263	9948	10603
42	5438	6283	7118	7940	8743	9519	10300	11062	11793
44	6010	6945	7868	8778	9668	10527	11392	12237	13046
46	6611	7640	8657	9659	10529	11586	12539	13471	14363
48	7241	8369	9484	10583	11658	12697	13742	14764	15744
50	7900	9131	10349	11549	12722	13858	15001	16118	17189
52	8588	9927	11252	12557	13834	15071	16315	17531	18697
54	9304	10756	12193	13608	14993	16335	17685	19004	20269
56	10049	11618	13172	14701	16199	17651	19110	20537	21906
58	10824	12514	14189	15837	17452	19016	20591	22130	23606
60	11627	13443	15244	17016	18751	20434	22127	23782	25370
62	12459	14406	16336	18237	20097	21903	23719	25494	27197
64	13320	15420	17467	19500	21491	23423	25366	27266	29089
66	14210	16432	18636	20806	22931	24994	27069	29098	31045
68	15128	17495	19843	22154	24418	26617	28827	30989	33064
70	16076	18591	21088	23545	25952	28291	30641	32940	35147
72	17052	19721	22371	24978	27533	30016	32510	34951	37294
74	18058	20885	23692	26454	29160	31792	34435	37022	39505
76	19092	22082	25051	27972	30835	33619	36416	39152	41780
78	20155	23312	26447	29533	32556	35498	38452	41343	44118
80	21247	24576	27882	31136	34325	37427	40543	43593	46520
82	22368	25873	29355	32782	36140	39408	42690	45902	48986
84	23517	27203	30866	34470	38002	41440	44892	48272	51516

STRUCTURAL - STEEL

TABLE A - MOMENTS OF INERTIA OF FOUR ANGLES.

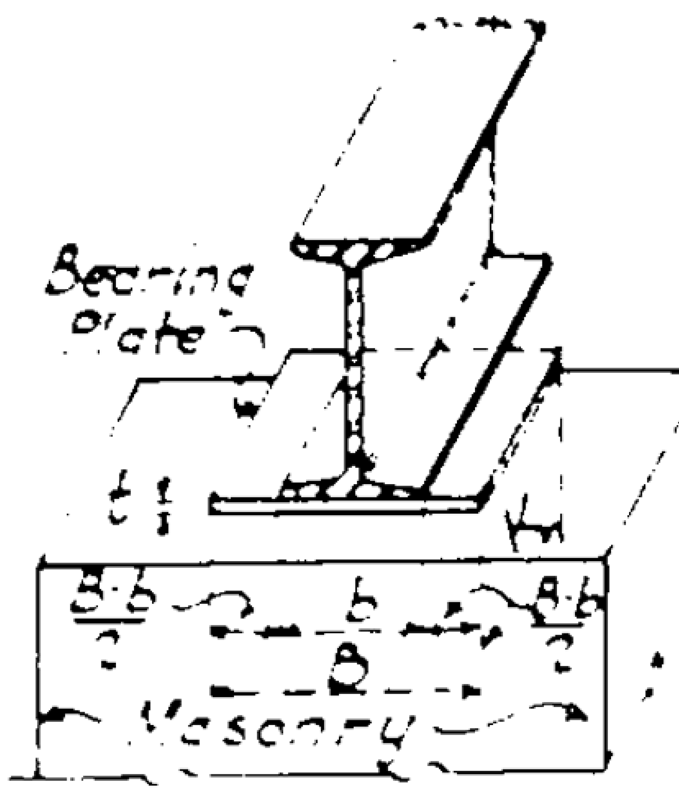
5 x 3½ ANGLES
SHORT LEGS OUT



THICKNESS	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4
AREA 4 Ls	10.24	12.20	14.12	16.00	17.88	19.68	21.48	23.24
d IN INCHES	MOMENTS OF INERTIA ABOUT AXIS X-X IN INCHES⁴ FOR VARIOUS DISTANCES BACK TO BACK OF ANGLES							
16	481	569	654	735	817	892	968	1038
18	627	743	856	962	1070	1170	1270	1363
20	794	942	1085	1221	1357	1487	1615	1735
22	982	1165	1342	1511	1682	1843	2003	2153
24	1190	1412	1628	1834	2042	2239	2434	2618
26	1419	1684	1942	2189	2438	2674	2908	3129
28	1668	1980	2284	2576	2869	3148	3424	3687
30	1937	2301	2655	2995	3337	3661	3984	4291
32	2227	2646	3054	3446	3840	4214	4587	4942
34	2538	3015	3481	3929	4379	4807	5233	5639
36	2869	3409	3936	4444	4953	5439	5921	6383
38	3220	3827	4419	4990	5564	6110	6653	7173
40	3592	4270	4931	5569	6210	6820	7427	8010
42	3984	4737	5471	6180	6892	7570	8245	8893
44	4397	5228	6039	6823	7610	8359	9105	9822
46	4831	5744	6636	7498	8363	9188	10009	10798
48	5284	6285	7260	8205	9152	10055	10955	11821
50	5759	6849	7913	8944	9977	10963	11945	12890
52	6254	7438	8594	9715	10838	11909	12977	14005
54	6769	8052	9304	10518	11734	12895	14052	15167
56	7305	8689	10041	11352	12667	13921	15170	16376
58	7861	9352	10807	12219	13635	14985	16332	17631
60	8437	10038	11601	13118	14639	16089	17536	18932
62	9035	10749	12424	14049	15678	17233	18783	20280
64	9652	11485	13274	15012	16753	18416	20073	21675
66	10291	12245	14153	16007	17864	19638	21406	23116
68	10949	13029	15060	17034	19011	20899	22782	24603
70	11628	13837	15996	18093	20194	22200	24201	26137
72	12328	14670	16959	19183	21412	23540	25663	27717
74	13048	15528	17951	20306	22666	24920	27168	29344
76	13789	16409	18971	21461	23956	26339	28716	31017

STRUCTURAL - STEEL

BEARING PLATES FOR STEEL BEAMS.



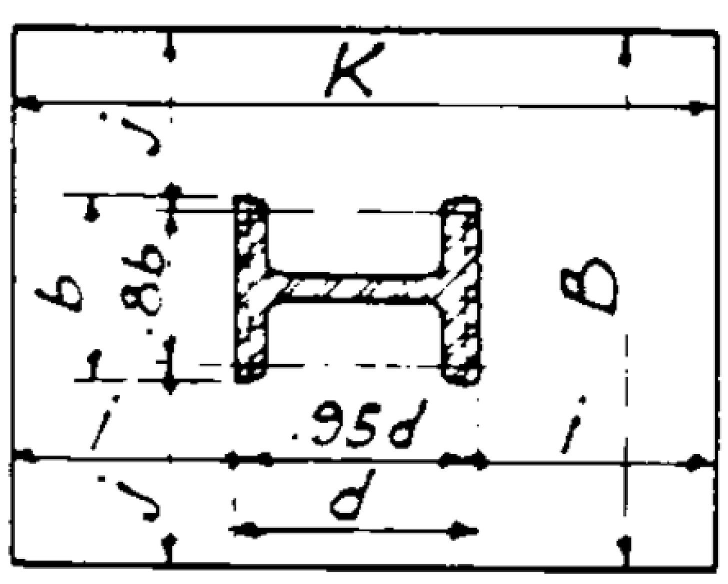
EXAMPLE: Given: Load = 40,000#; safe bearing pressure of 200#/□"; K = 10"; b = 12". To find size and thickness of plate. $B = \frac{40{,}000}{10 \times 200} = 20''$. Then $B-b = 20-12 = 8''$. $B(B-b) = 20 \times 8 = 160$. Therefore from table $t = 1\frac{1}{4}''$. Bearing plate = $10 \times 20 \times 1\frac{1}{4}''$.

f = Unit steel stress 20,000#/□" (A.I.S.C.)
p = Safe pressure on masonry #/□"
t = Thickness of plate in inches as computed by $t = \sqrt{B(B-b)\frac{3p}{4f}}$

TABLE A - VALUES OF PRODUCT B(B-b) FOR VARIOUS THICKNESSES OF PLATES.

t \ p	70	100	110	125	150	200	250	300	325	350	400	450	500	550	600	625	750	875
3/8	54	38	34.0	30.2	25.1	18.8	15.1	12.5	11.6	10.8	9.4	8.4	7.5	6.8	6.3	6.0	5.0	4.3
1/2	95	67	60.6	53.3	44.4	33.3	26.7	22.2	20.5	19.1	16.7	14.8	13.3	12.1	11.1	10.7	8.9	7.6
5/8	148	104	94.5	83.3	69.4	52.0	41.7	34.7	32.0	29.8	26.0	23.1	20.8	18.9	17.4	16.7	13.9	11.9
3/4	214	150	136	120	100	75.0	60.0	50.0	46.2	43.0	37.4	33.3	30.0	27.3	25.0	24.0	20.0	17.2
7/8	291	204	185	163	136	102	81.4	68.0	62.8	58.4	51.0	45.3	40.8	37.1	34.0	32.7	27.2	23.3
1	381	267	243	214	178	133	107	89.0	82.0	76.3	66.7	59.3	53.3	48.5	44.5	42.7	35.6	30.5
1¼	595	417	379	333	278	209	167	139	129	119	105	92.8	83.3	76.8	69.5	66.7	55.7	47.7
1½	857	600	546	480	400	300	240	200	185	172	150	134	120	109	100	96.1	80.0	68.6
2	1524	1065	970	853	712	533	428	356	328	305	267	237	214	194	178	171	143	122
2½	2380	1670	1515	1333	1112	833	668	556	513	477	417	371	334	303	278	267	222	191
3	3430	2400	2180	1920	1600	1200	962	800	738	687	600	533	481	437	400	385	320	274
3½	4670	3270	2970	2620	2180	1635	1310	1090	1005	933	817	726	653	594	545	523	437	374
4	6100	4270	3880	3420	2850	2140	1710	1420	1313	1220	1068	948	853	777	712	684	570	488

COLUMN BASE PLATES.



EXAMPLE: Given: Load = 400,000#; safe bearing pressure of 875#/□"; B = 20"; b = 12"; d = 12". To find size and thickness of plate. Area required = $\frac{400000}{875} = 457$□"; $K = \frac{457}{20} = 23''$.
$2j = B - .8b \therefore j = \frac{20-9.6}{2} = 5.2$
$2i = K - .95d \therefore i = \frac{23-11.4}{2} = 5.8$ } Use larger one i = 5.8.
∴ From table $t = 2\frac{1}{4}''$ B.P. = $20'' \times 23'' \times 2\frac{1}{4}''$

f = Unit steel stress 20,000#/□" (A.I.S.C.)
p = Safe pressure on masonry #/□"
t = Thickness of plate in inches as computed by $t = i \text{ or } j\sqrt{\frac{p}{6666}}$
(Use i or j whichever is greater.)

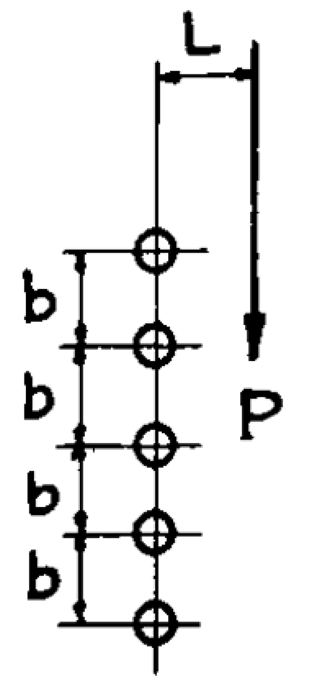
TABLE B - VALUES OF i OR j FOR VARIOUS THICKNESSES OF PLATES.

t \ p	110	200	250	500	625	750	875	t \ p	110	200	250	500	625	750	875
1	7.78	5.77	5.17	3.65	3.26	2.98	2.76	3½	27.2	20.2	18.1	12.8	11.4	10.4	9.65
1¼	9.73	7.22	6.45	4.57	4.07	3.73	3.45	4	31.1	23.1	20.6	14.6	13.0	11.9	11.0
1½	11.6	8.66	7.75	5.48	4.88	4.47	4.14	4½	35.0	25.9	23.2	16.4	14.7	13.4	12.4
1¾	13.6	10.1	9.04	6.38	5.71	5.22	4.83	5	38.9	28.8	25.8	18.2	16.3	14.9	13.8
2	15.5	11.5	10.3	7.30	6.52	5.96	5.52	5½	42.7	31.7	28.4	20.1	17.9	16.4	15.2
2¼	17.5	13.0	11.6	8.22	7.33	6.71	6.21	6	46.6	34.6	31.0	21.9	19.6	17.9	16.5
2½	19.4	14.4	12.9	9.13	8.15	7.45	6.90	6½	50.6	37.5	33.6	23.7	21.2	19.4	17.9
2¾	21.4	15.9	14.2	10.0	8.97	8.20	7.58	7	54.4	40.3	36.2	25.6	22.8	20.8	19.3
3	23.3	17.3	15.5	11.0	9.77	8.94	8.28	8	62.2	46.2	41.3	29.2	26.1	23.8	22.0

STRUCTURAL - STEEL

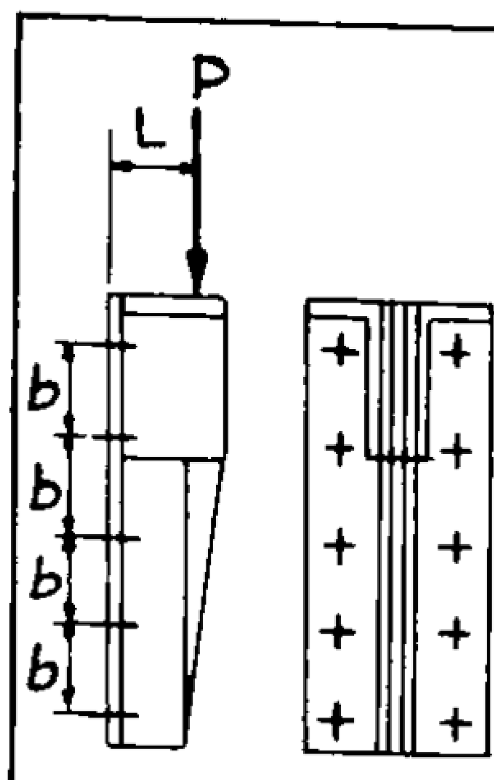
TABLE A - SAFE LOADS ON ECCENTRIC CONNECTIONS.

For 7/8"ø Rivets - Max. Stress on Extreme Rivet = 9020#, Single Shear, A.I.S.C. Code.
L = Moment Arm in Inches. N = Total No. of Rivets in group. P = Load in kips.



b = 3"

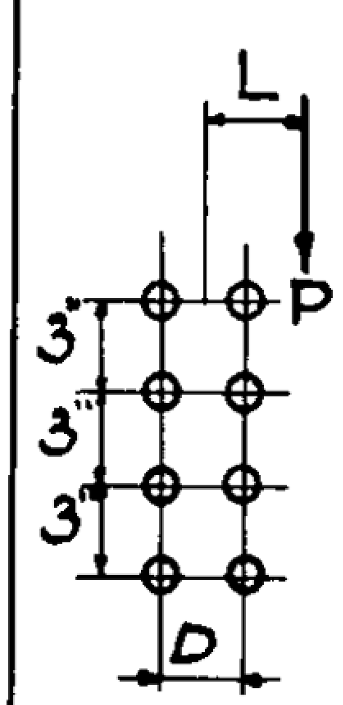
N \ L	1	2	3	4½	6	9	12	15	18
2	15.3	10.8	8.0	5.8	4.3	3.0	2.2	1.8	1.5
3	24.3	18.9	15.3	11.1	8.6	5.9	4.4	3.6	3.0
4	33.4	28.0	23.4	17.4	13.5	9.9	7.4	6.0	5.0
5	42.3	37.9	31.6	25.0	19.8	14.4	10.8	8.8	7.4
6	52.2	47.0	41.3	32.6	27.0	19.8	15.2	12.6	9.9
7	61.3	56.8	50.5	41.8	35.0	25.2	19.8	16.2	13.5
8	70.3	65.8	60.4	51.2	43.3	32.4	25.2	20.7	17.1
9	79.3	75.8	69.5	60.4	52.5	39.7	31.6	25.2	21.6
10	88.3	84.8	79.4	69.2	61.3	46.9	37.8	30.7	26.2
11	98.4	94.8	88.3	79.4	70.2	55.0	44.2	37.0	31.6
12	107.0	103.8	98.4	88.6	79.3	63.1	51.4	43.3	37.0



b = 3"

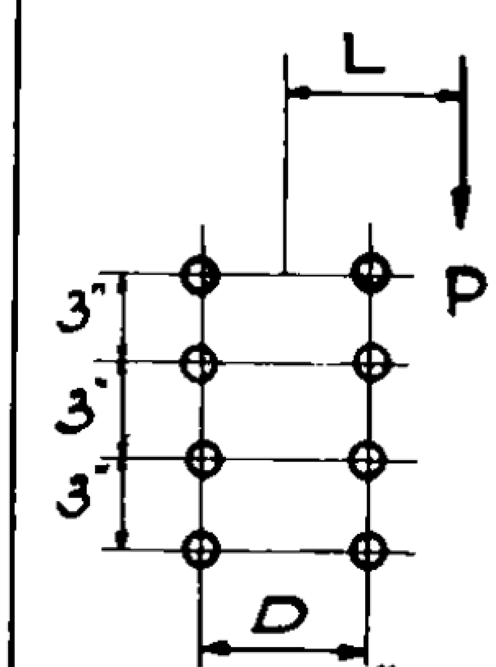
EXAMPLE #1: Given: L = 3", N = 10, 7/8"ø Rivets, Single Shear. Required: P From table P = 63.2.

N \ L	1	2	3	4½	6	9	12	15	18
4	30.6	21.6	16.0	11.6	8.6	6.0	4.4	3.6	3.0
6	48.6	37.8	30.6	22.2	17.2	11.8	8.8	7.2	6.0
8	66.8	56.0	46.8	34.8	27.0	19.8	14.6	12.0	10.0
10	84.6	75.8	$\boxed{63.2}$	50.0	39.6	28.8	21.6	17.6	14.8
12	104.4	94.0	82.6	65.2	54.0	39.6	30.4	25.2	19.8
14	122.6	118.6	101.0	83.6	70.0	50.4	39.6	32.4	27.0
16	140.6	131.6	120.8	102.4	86.6	64.8	50.4	41.4	34.2
18	158.6	151.6	139.0	120.8	105.0	79.4	63.2	50.4	43.2
20	176.6	169.6	158.8	138.4	121.6	93.8	75.6	61.4	52.4
22	196.8	189.6	176.6	158.8	140.4	110.0	88.4	74.0	63.2
24	214.0	207.6	196.8	177.2	158.2	126.2	102.8	86.6	74.0



D = 3"

N \ L	1	2	3	4½	6	9	12	15	18
4	26.2	20.2	16.2	12.3	9.9	7.2	5.7	4.6	3.9
6	44.2	34.1	28.5	22.2	18.0	12.9	10.0	8.2	6.9
8	62.2	51.7	43.3	34.0	27.8	20.0	15.3	12.7	10.8
10	81.0	69.7	59.4	47.7	39.4	28.8	22.4	18.3	15.4
12	100.0	88.5	77.2	63.1	52.6	38.8	30.6	25.1	21.1
14	119.0	107.5	95.8	79.7	67.5	50.4	39.1	32.5	27.6
16	137.0	126.2	114.1	97.0	83.1	62.9	50.1	41.2	35.1
18	156.0	145.0	133.1	115.2	99.0	75.5	61.0	51.0	43.4
20	174.0	164.0	153.1	134.2	106.8	90.0	73.8	61.3	52.1
22	193.0	183.0	171.0	152.0	134.1	107.6	85.5	72.5	62.0
24	212.0	201.5	188.7	169.8	153.0	125.5	100.5	84.6	72.4



D = 5½"

EXAMPLE #2: Given: L = 6", N = 8, 7/8"ø Rivets, S.S. Required: P From table P = 30.6.

N \ L	1	2	3	4½	6	9	12	15	18
4	27.9	22.6	18.9	15.3	12.6	9.9	7.3	6.3	5.4
6	44.1	37.0	30.6	25.2	20.8	15.3	12.6	9.9	9.0
8	61.3	57.3	45.1	36.6	$\boxed{30.6}$	22.6	18.1	15.3	12.6
10	79.3	69.5	60.4	49.6	41.5	31.6	25.3	20.8	17.1
12	98.4	86.6	76.5	64.1	54.1	40.6	32.5	27.1	23.4
14	116.1	105.5	93.8	79.4	67.7	52.3	41.4	34.3	29.8
16	135.1	123.5	111.9	96.5	83.0	64.0	51.4	43.3	37.0
18	153.0	142.6	130.8	114.5	99.3	77.5	62.2	52.3	44.2
20	172.0	161.5	149.9	131.5	115.5	91.1	74.0	62.2	53.2
22	191.0	180.5	168.8	150.5	133.5	106.4	87.5	73.1	63.1
24	202.0	199.0	187.7	168.5	151.5	121.8	101.1	84.7	73.1

TABLE B - COEFFICIENT "K".

K × P in Table A gives loads for other Rivet Conditions.
S.S. = Single Shear, t = Web or Plate thickness, D.S. = Double Shear.

A.I.S.C. CODE

	SINGLE BEAR			S.S.	DOUBLE BEARING						D.S.
t	1/4	5/16	3/8		1/4	5/16	3/8	7/16	1/2	9/16	
1"ø	.88	1.11	1.33	1.30	1.10	1.39	1.66	1.94	2.21	2.49	2.61
7/8"ø	.77	.97	–	1.00	.97	1.21	1.45	1.70	$\boxed{1.94}$	–	2.00
3/4"ø	.66	–	–	.73	.83	1.04	1.25	1.46	–	–	1.47

N.Y. CITY CODE

	SINGLE BEAR.				S.S.	DOUBLE BEARING							D.S.
t	1/4	5/16	3/8	7/16		1/4	5/16	3/8	7/16	1/2	9/16	5/8	
1"ø	.66	.83	1.00	1.16	1.17	.83	1.04	1.24	1.46	1.66	1.87	2.08	2.34
7/8"ø	.58	.73	.87	–	.90	.73	.91	1.09	1.27	1.46	1.64	–	1.80
3/4"ø	.50	.62	–	–	.66	.62	.78	.93	1.08	1.25	–	–	1.32

EXAMPLE: In Example #2, if 7/8"ø Rivets are in Double Bearing, A.I.S.C. Code, on ½" Plate find in table above K = 1.94, then K × P = 1.94 × 30.6 = 59.4 Kips.

Note: Where b = 2½ for single line and b = 2½ and D = 2½ for Double line, use 85% of "P" for approximate Values.

STRUCTURAL - STEEL

TABLE A – LALLY COLUMNS.*

SAFE LOADS IN 1,000 LBS.

	Outside Dia. of Column in Inches	Weight in Lbs. per Ft.	Section Modulus	Area of Steel Sq. In.	Area of Concrete in Sq. In.	Max. Height in Ft. l/r=120	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Eccentric Loads* equivalent direct load in 1000 lbs. to be added for each 10,000 in. lbs. Moment
Light Weight	3½	13	1.3	1.3	8.4	11.9	26	24	22	20	18	16	15									
Light Weight	4	17	1.9	1.6	10.9	13.7	36	33	31	29	27	25	22	20								
Heavy Weight	3½	15	2.1	2.2	7.4	11.6	38	35	32	29	27	24										13.3
Heavy Weight	4	20	2.9	2.7	9.9	13.3	49	46	43	40	37	34	31	28								11.9
Heavy Weight	4½	24	3.9	3.2	12.7	15.1	62	59	55	52	49	46	42	39	36	33						10.8
Heavy Weight	5	29	5.2	3.7	16.0	16.8	76	72	69	65	62	58	55	51	48	44	41	37				9.8
Heavy Weight	5½	36	6.8	4.3	20.0	18.7	92	88	85	81	77	73	70	66	62	58	55	51	47	43		8.7
Heavy Weight	6⅝	49	10.7	5.6	28.9	22.4	128	124	120	116	112	108	103	99	95	91	87	83	78	74	70	7.4
Heavy Weight	7⅝	64	15.3	6.9	38.7	25.9	166	161	157	152	148	143	139	134	130	125	121	116	111	107	102	6.7
Heavy Weight	8⅝	81	21.2	8.4	50.0	29.3	211	206	201	196	191	186	181	176	171	166	161	156	151	146	141	5.8
Heavy Weight	9⅝	100	27.6	10.0	62.8	32.8	259	254	248	243	237	232	227	221	216	210	205	199	194	188	183	5.4
Heavy Weight	10¾	123	38.6	11.9	78.9	36.7	319	313	307	301	295	289	284	278	272	266	260	254	248	242	236	4.9
Heavy Weight	12¾	169	56.7	14.6	113.1	43.7	422	415	409	402	396	389	383	376	370	363	357	350	344	337	331	4.2

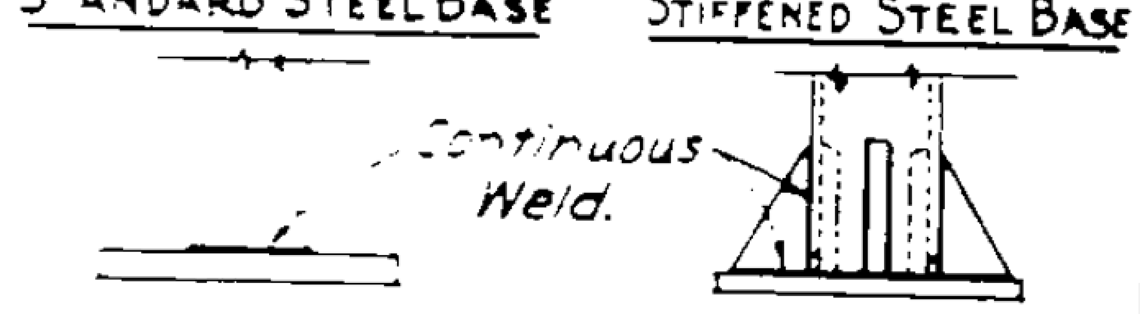
(Unbraced Length of Column in Feet: columns 6 to 20.)

Heavy lines denote the greatest safe length for $l/r = 120$.
Column Formula: $P = (A_c + 12 A_s)(1600 - 24\, l/d)$. In which P = Safe carrying capacity in pounds, A_c = Area of concrete in sq. in., A_s = Area of steel in sq. in., l = Length of column in inches, d = Diameter of column in inches.

* For each 10,000 in. lbs. unbalanced moment on the column add the number of kips shown to the sum of all the vertical loads.

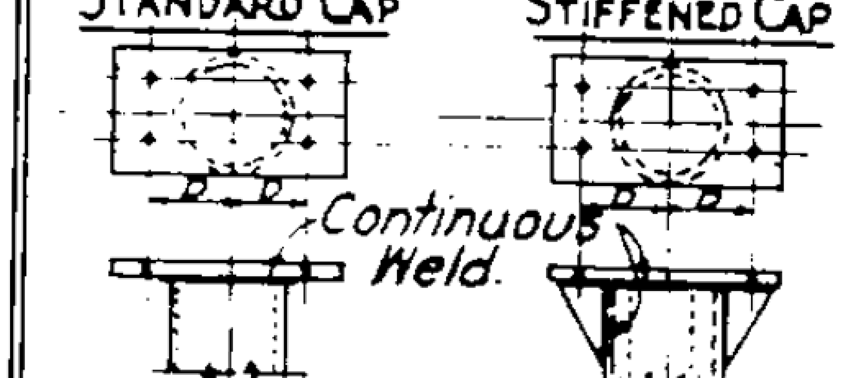
TABLE B – STANDARD BASES & CAPS.*

Standard Steel Base — Stiffened Steel Base



Assumed Bearing - 500 Lbs./Sq. In.

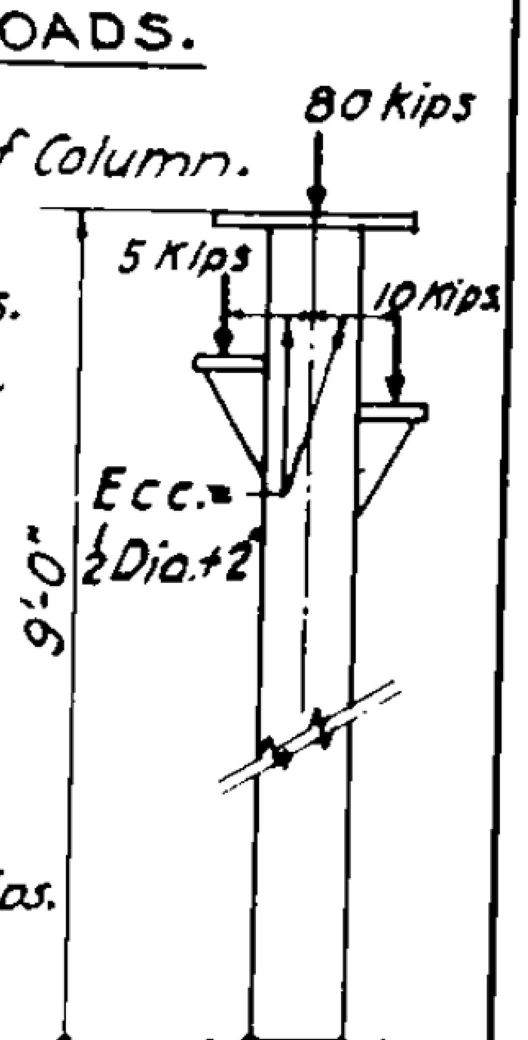
Standard Cap — Stiffened Cap



Diam. of Column	Size of Base Plate	Safe Load in 1,000 Lbs.	Thickness of Base Plate: Standard Base	Thickness of Base Plate: Stiffened Base	Distance "D": Standard Cap	Distance "D": Stiffened Cap	Thickness of Cap
3½"	8"x8"	32.0	⅝"	½"	3¼"	4¼"	½"
4"	9"x9"	40.5	¾"	½"	3½"	4½"	½"
4½"	10"x10"	50.0	⅞"	½"	3¾"	4¾"	½"
5"	12"x12"	72.0	1"	½"	4"	5"	⅝"
5½"	14"x14"	98.0	1¼"	¾"	4¼"	5¼"	⅝"
6⅝"	16"x16"	128.0	1⅜"	¾"	4¾"	6¼"	¾"
7⅝"	18"x18"	162.0	1⅝"	¾"	5"	6¾"	¾"
8⅝"	20"x20"	200.0	1¾"	¾"	5¾"	7¼"	¾"
9⅝"	22"x22"	242.0	1⅞"	¾"	6¼"	7¾"	¾"
10¾"	24"x24"	288.0	2"	⅞"	7"	8¼"	¾"
12¾"	28"x28"	392.0	2¼"	⅞"	8"	9"	¾"

* Adapted from the Lally Col. Co.

Example Of Design Of Lally Columns With Eccentric Loads.



Given: 9'-0" Unbraced Height of Column.
Concentric Load = 80 kips.
One eccentric load of 10 kips.
" " " " 5 kips.
See sketch.

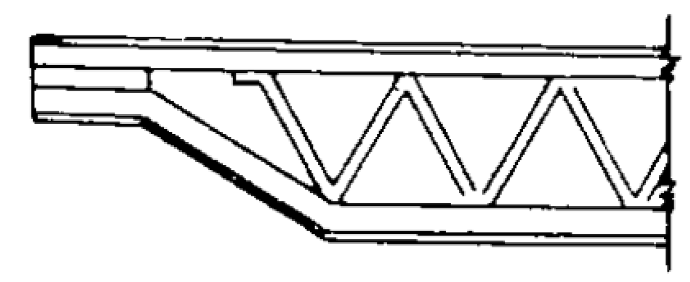
Required size of column.

Solution: Assume a column 6⅝" Diameter.
Direct load = 80+10+5 = 95 kips.
Resultant eccentric load = 10 − 5 = 5 kips.
Bending Moment = $5\left(\frac{6\frac{5}{8}}{2}+2\right)$ = 26,500 in. lbs.
From Table A for a 6⅝" Dia. Col. The equivalent direct load = $\frac{26,500}{10,000} \times 7.4 = 19.5$ kips.
Equivalent Total Load = 95 + 19.5 = 114.5 kips.
From Table A a 6⅝" diameter with 9'-0" unbraced height is good for 116 kips. ∴ A 6⅝" Dia. Col. is required.

STRUCTURAL - STEEL

In accordance with
Design Specifications
of Steel Joist Institute.

OPEN WEB JOIST
ALLOWABLE LOAD TABLES



Joist	Span in Feet	Safe Load Lbs.	Req'd Spacing for Loads per Sq. Ft. Shown														
			80	90	100	110	115	120	125	130	140	150	160	170	180	190	200
81	8	2460								30	28	26	24	23	22	19	18
	9	2180		30	28	26	25	24	23	22	20	19	18	17	16	15	14
	10	1970	30	26	24	22	21	20	19	18	17	16	15	14	13	12	
	11	1780	24	22	19	18	17	16	15	15	14	13	12				
	12	1635	20	18	16	15	14	13	13	12							
	13	1510	17	15	14	13	12										
8"	14	1400	15	13	12												
82	10	3500									30	28	26	24	23	22	21
	11	3180					30	29	28	26	25	23	22	20	19	18	17
	12	2920			29	26	25	24	23	22	21	19	18	17	16	15	14
	13	2690	30	28	25	23	22	21	20	19	18	16	15	14	14	13	12
	14	2500	26	24	21	20	19	18	17	16	15	14	13	12			
	15	2330	23	21	18	17	16	15	15	14	13	12					
8"	16	2190	20	18	16	15	14	13	13	12							
102	12	3500					30	29	28	26	25	23	22	20	19	18	17
	13	3230			30	28	26	25	24	23	21	20	19	18	17	16	15
	14	3000	30	28	26	23	22	21	20	20	18	17	16	15	14	13	12
	15	2810	28	25	22	20	19	18	18	17	16	15	14	13	12		
	16	2630	24	22	20	18	17	16	16	15	14	13	12				
	17	2470	22	19	17	16	15	14	14	13	12						
	18	2330	19	17	15	14	13	13	12	12							
	19	2210	17	15	14	13	12										
10"	20	2100	16	14	12												
103	12	3900								30	28	26	24	23	21	20	19
	13	3900						30	29	28	26	24	22	21	20	19	18
	14	3900				30	29	28	27	26	24	22	21	19	18	17	17
	15	3640			29	26	25	24	23	22	21	19	18	17	16	15	14
	16	3420		28	25	23	22	21	20	19	18	17	16	15	14	13	12
	17	3220	28	25	23	21	20	19	18	17	16	15	14	13	12	12	
	18	3040	25	22	20	19	18	17	16	15	14	13	12	12			
	19	2880	22	20	18	16	16	15	14	14	13	12					
10"	20	2730	20	18	16	15	14	13	13	12							
104	12	4400										29	28	26	24	23	22
	13	4400								30	29	27	25	24	22	21	20
	14	4400							30	29	27	25	23	22	21	20	19
	15	4400					30	29	28	27	25	23	22	20	19	18	17
	16	4170			30	28	27	26	25	24	22	21	19	18	17	16	15
	17	3920		30	28	25	24	23	22	21	19	18	17	16	15	14	13
	18	3710	30	27	25	23	22	21	20	19	18	16	15	14	14	13	12
	19	3510	28	25	22	20	19	18	18	17	16	15	14	13	12		
10"	20	3340	25	22	20	18	17	16	16	15	14	13	12				
123	15	4090				30	28	27	26	25	23	22	20	19	18	17	16
	16	3840			29	28	26	25	24	23	22	20	19	18	17	15	14
	17	3610		28	25	23	22	21	20	19	18	17	16	15	14	13	12
	18	3410	28	25	23	21	20	19	18	17	16	15	14	13	13	12	
	19	3230	25	23	20	18	18	17	16	15	14	13	13	12			
	20	3060	23	20	18	17	16	15	15	14	13	12					
	21	2920	21	18	16	15	14	14	13	13	12						
	22	2790	19	17	15	14	13	12	12								
	23	2670	17	15	14	13	12										
12"	24	2550	16	14	13												
124	15	4600							30	28	26	24	23	21	20	19	18
	16	4600					30	29	28	26	25	23	21	20	19	18	17
	17	4510			30	29	28	26	25	24	23	21	20	19	18	17	16
	18	4260		30	28	26	25	24	23	22	20	19	18	17	16	15	14
	19	4040	30	28	25	23	22	21	20	19	18	17	16	15	14	13	12
	20	3830	28	25	23	21	20	19	18	17	16	15	14	13	12	12	
	21	3650	26	23	21	19	18	17	17	16	15	14	13	12			
	22	3480	24	21	19	17	16	16	15	14	13	12					
	23	3330	22	19	17	16	15	14	14	13	12						
12"	24	3190	20	18	16	14	14	13	13	12							
125	15	5000								30	28	26	25	23	22	21	20
	16	5000							30	28	26	25	23	22	21	20	19
	17	5000						30	28	27	25	23	22	20	19	18	17
	18	5000					30	29	28	25	24	22	21	19	18	17	16
	19	4990			30	29	28	26	25	24	22	21	20	18	17	16	15
	20	4740		30	28	26	25	24	23	22	20	19	18	17	16	15	14
	21	4510	30	28	26	23	22	21	20	19	18	17	16	15	14	13	13
	22	4300	29	26	23	21	20	19	19	18	17	16	15	14	13	12	
	23	4120	27	24	21	19	19	18	17	16	15	14	13	12	12		
12"	24	3950	24	22	20	15	17	16	16	15	14	13	12				
126	15	5400									30	28	27	25	24	23	22
	16	5400								30	29	27	25	24	22	21	20

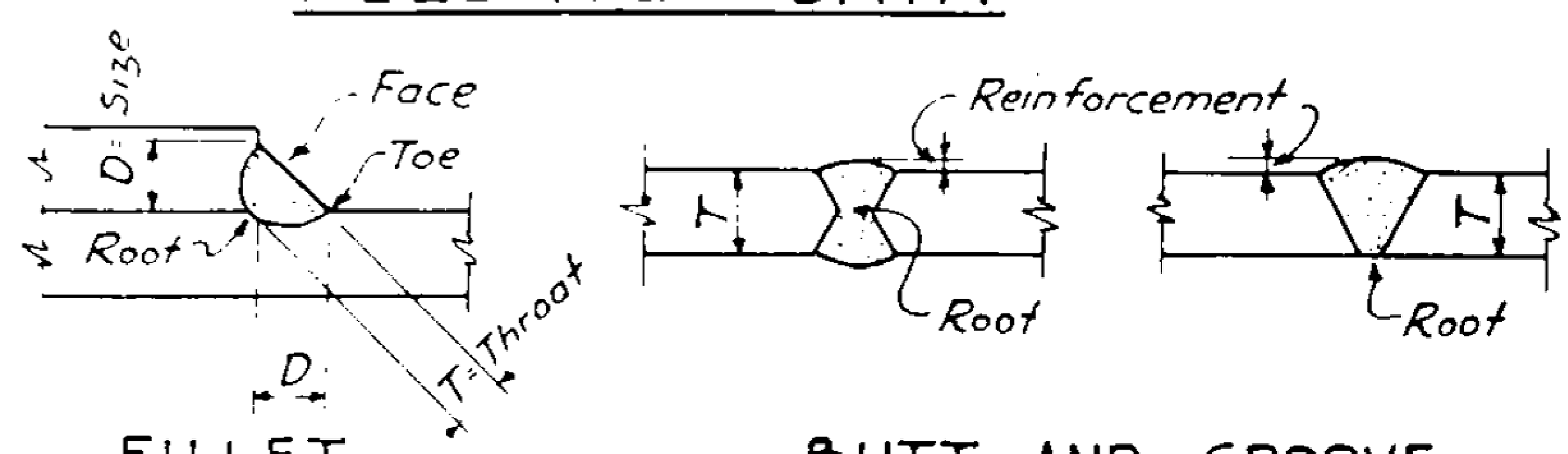
Joist	Span in Feet	Safe Load Lbs.	Req'd Spacing for Loads per Sq. Ft. Shown														
			80	90	100	110	115	120	125	130	140	150	160	170	180	190	200
126 Con'td	17	5400							30	29	27	25	24	22	21	20	19
	18	5400						30	29	28	26	24	22	21	20	19	18
	19	5400					30	28	27	26	24	22	21	20	19	18	17
	20	5400				30	28	27	26	25	23	21	20	19	18	17	16
	21	5400			30	28	27	26	25	23	22	20	19	18	17	16	15
	22	5300		29	28	26	25	24	23	22	20	19	18	17	16	15	14
	23	5060		28	26	24	23	22	21	20	19	18	17	16	15	14	13
12"	24	4860	30	26	24	22	21	20	19	18	17	16	15	14	13	12	
145	16	5800										29	27	25	24	23	22
	17	5800									29	27	25	24	22	21	20
	18	5780								30	27	25	24	22	21	20	19
	19	5480					30	29	28	26	25	23	22	20	19	18	17
	20	5200			30	28	27	26	25	24	22	21	19	18	17	16	15
	21	4950		30	28	26	25	24	23	22	20	19	18	17	16	15	14
	22	4730	30	28	26	24	22	21	20	19	18	17	16	15	14	13	13
	23	4520	29	26	23	21	20	19	19	18	17	16	15	14	13	12	
	24	4340	26	24	22	20	19	18	17	16	15	14	13	12	12		
	25	4160	25	22	20	18	17	16	16	15	14	13	12				
	26	4000	23	20	18	17	16	15	15	14	13	12					
	27	3850	21	19	17	16	15	14	13	13	12						
14"	28	3720	20	18	16	14	14	13	13	12							
146	16	6200										30	29	27	26	24	23
	17	6200										29	27	26	24	23	22
	18	6200									30	27	26	24	23	22	21
	19	6200								30	28	26	24	23	22	20	19
	20	6200							30	29	26	25	23	22	20	19	18
	21	6200						30	28	27	25	23	22	21	20	19	18
	22	6200				30	29	28	27	26	24	22	21	20	19	18	17
	23	5940			30	28	27	26	25	24	22	20	19	18	17	16	15
	24	5690		30	28	26	25	24	23	22	20	19	18	17	16	15	14
	25	5450		29	28	26	23	22	21	20	19	18	17	16	15	14	13
	25	5250	30	27	24	22	21	20	19	18	17	16	15	14	13	13	12
	27	5050	28	25	22	20	19	18	18	17	16	15	14	13	12		
14"	28	4880	26	23	21	19	18	17	17	16	15	14	13	12			
147	16	6800												30	28	26	25
	17	6800											30	28	26	25	24
	18	6800										30	28	26	25	24	23
	19	6800									30	28	26	25	24	22	21
	20	6800									29	27	25	24	23	21	20
	21	6800								30	28	26	24	23	21	20	19
	22	6800							30	28	26	25	23	22	20	19	18
	23	6800						30	28	27	25	23	22	21	20	19	18
	24	6800					30	28	27	26	24	22	21	20	19	18	17
	25	6560				28	27	26	25	24	22	21	20	19	18	17	16
	26	6300			29	26	25	24	23	22	21	19	18	17	16	15	14
	27	6070		30	27	24	23	22	21	20	19	18	17	16	15	14	13
14"	28	5850	30	28	25	23	22	21	20	19	18	17	16	15	14	13	12
166	20	6400								29	27	25	24	22	21	20	19
	21	6400						30	29	28	26	24	23	21	20	19	18
	22	6400					30	29	28	27	25	23	22	20	19	18	17
	23	6400				30	29	28	26	25	24	22	21	19	18	17	17
	24	6400				29	28	27	25	24	23	21	20	19	18	17	16
	25	6180			30	27	26	25	24	23	21	20	19	18	17	16	15
	26	5950		30	27	25	24	23	22	21	19	18	17	16	15	14	14
	27	5730		28	25	23	22	21	20	19	18	17	16	15	14	13	12
	28	5520	30	26	24	21	20	20	19	18	17	16	15	14	13	12	
	29	5340	28	24	22	20	19	18	18	17	16	15	14	13	12		
	30	5150	26	23	20	19	19	17	16	15	15	14	13	12			
	31	4990	24	21	19	17	17	16	15	15	14	13	12				
16"	32	4840	22	20	18	16	15	15	14	14	13	12					
167	20	7200									30	28	26	25	24	23	22
	21	7200									29	27	25	24	23	21	20
	22	7200								30	28	26	24	23	22	20	19
	23	7200							30	29	27	25	23	22	21	20	19
	24	7200						30	29	28	25	24	22	21	20	19	18
	25	7200					30	28	27	26	24	23	21	20	19	18	17
	26	7200				30	29	27	26	25	24	22	20	19	18	17	16
	27	6940			30	28	27	26	24	23	22	20	19	18	17	16	15
	28	6690			28	26	25	24	23	22	20	19	18	17	16	15	14
	29	6460		30	26	24	23	22	21	20	19	18	17	16	15	14	13
	30	6240	30	28	25	23	22	21	20	19	18	17	16	15	14	13	12
	31	6050	29	26	23	21	20	19	19	18	17	16	15	14	13	12	
16"	32	5860	28	24	22	20	19	18	17	17	16	15	14	13	12		

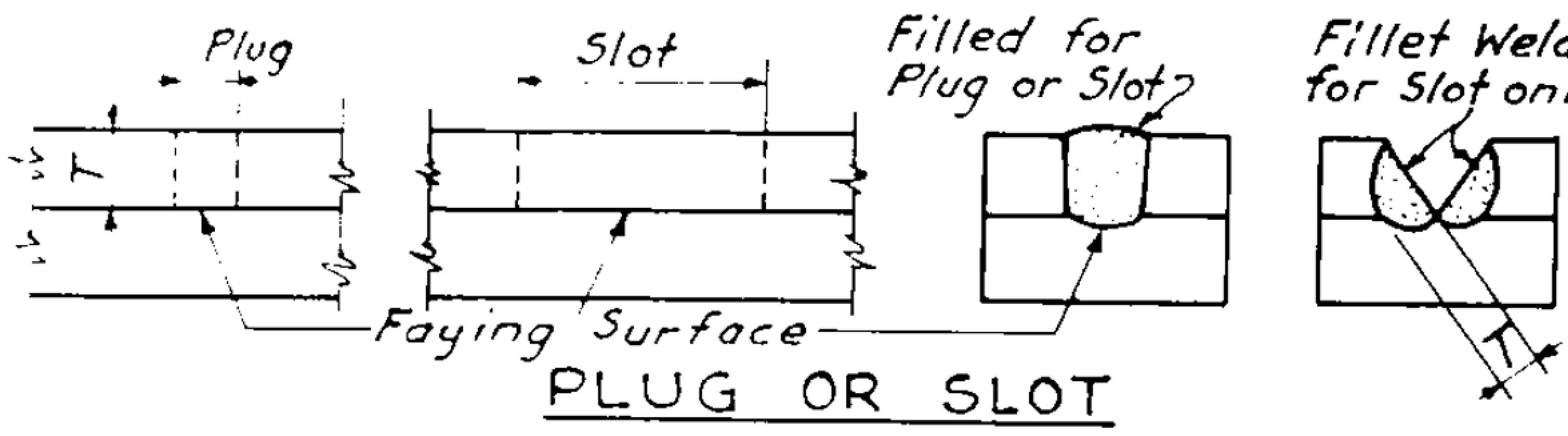
Maximum recommended spacing of open web joists is 24" for floors and 30" for roofs.
All floor joists spanning over 12'0" should be stiffened with a structural safety header at midspan in addition to the rigid bracing spaced 6'0" o.c. maximum.

*Adapted from Singleton, Manual of Structural Design, H.M. Ives & Sons

STRUCTURAL - STEEL

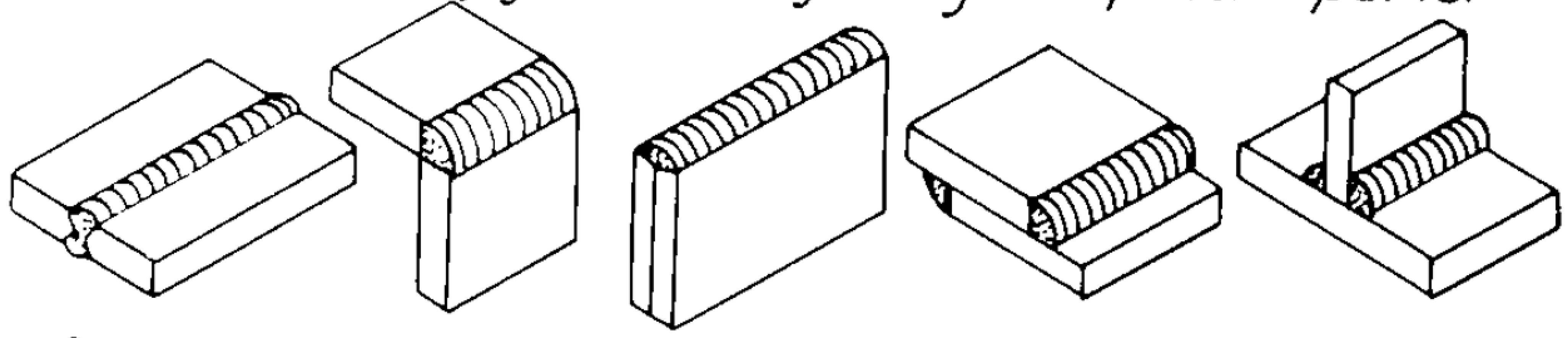
WELDING DATA





PLUG OR SLOT

These types of welds are used separately or in combination in making joints or in joining component parts.



TYPES OF JOINTS

Details of all joints shall comply with all the requirements for prequalified joints of the American Welding Soc. Code.

TABLE A - SIZES OF FILLET WELDS

Minimum Size of Fillet Weld - Inches	Maximum Thickness of Part in Inches	Maximum Size
3/16"	1/2"	Size assumed in design of connection shall be such that allowable stresses in adjacent base material shall not be exceeded.
1/4"	3/4"	
5/16"	1 1/4"	
3/8"	2"	
1/2"	6"	
5/8"	over 6"	

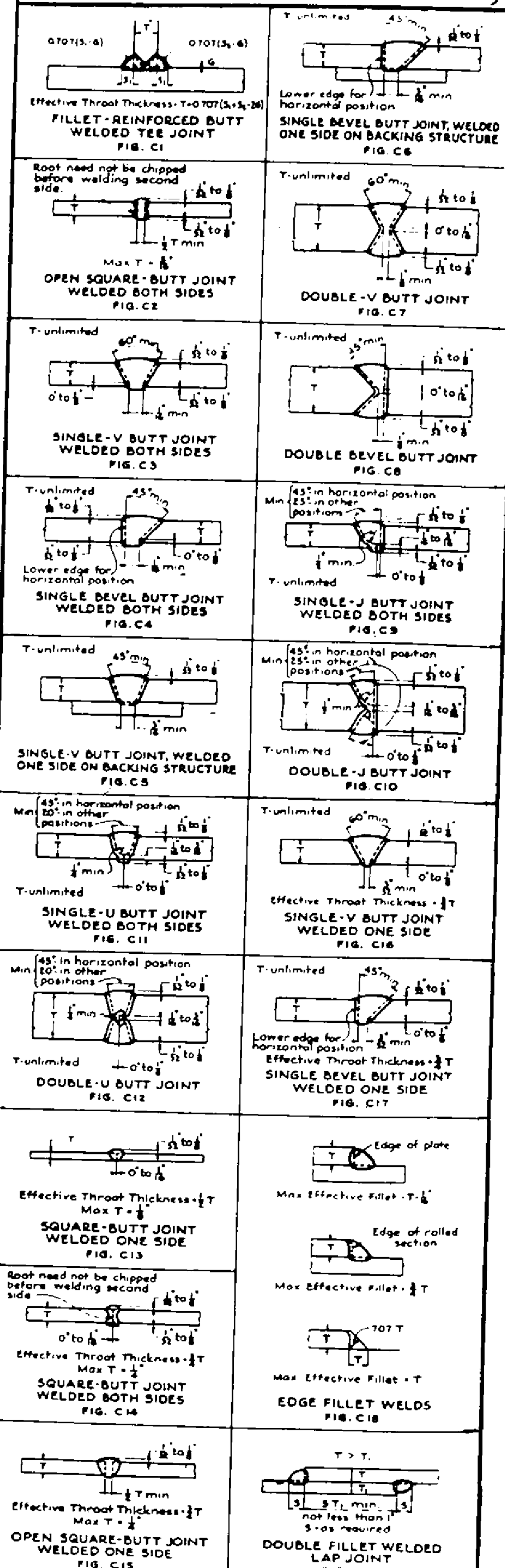
LENGTH OF WELDS

The effective length of fillet welds shall be the overall length of full size fillet including returns around corners.
The effective length of butt weld shall be the width of part joined.
The effective length of fillet welded Plug or slot welds shall be the length of the center line of weld through the center plane through throat.

EFFECTIVE AREAS OF WELD METAL

Butt and Fillet Weld = Effective length times throat thickness.
Filled Plug or Slot Weld = Nominal cross-section of hole or slot in plane of faying surface.
Fillet Welded Plug or Slot Welds = Same as Fillet Welds.

SKETCHES ILLUSTRATIVE OF JOINTS PREQUALIFIED IN A.W.S. CODE. (ALSO, FILLET WELDED JOINTS ARE PREQUALIFIED.)



Adapted from Welding Handbook American Welding Society

STRUCTURAL - STEEL

DESIGN OF WELDS

P = LOAD IN KIPS. D = WELD SIZE IN INCHES. T = THROAT IN INCHES. L = LENGTH IN INCHES.

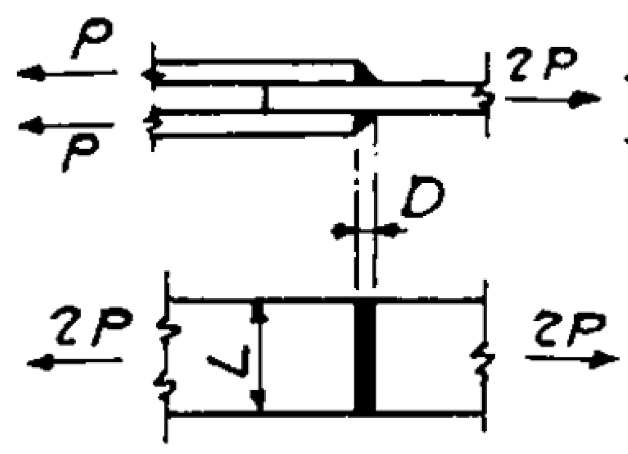


FIG. A

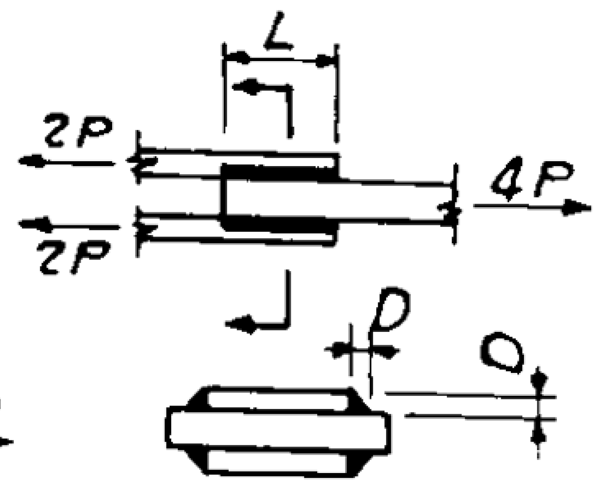


FIG. B

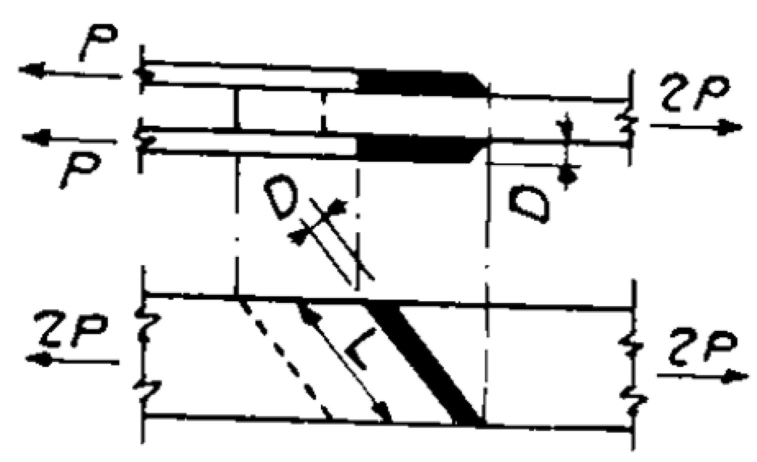
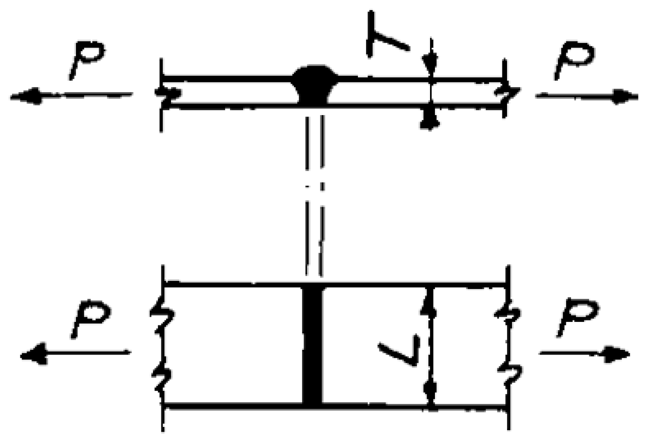


FIG. C

DIRECT LOAD ON FILLET WELDS - FIG. A, B, C.

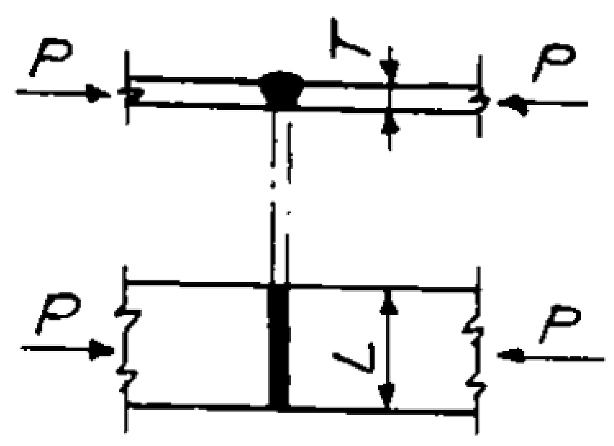
$P = 9.6 \times D \times L$ or $13.6\ T \times L$

$T = .707\ D$ for Fillet Weld.



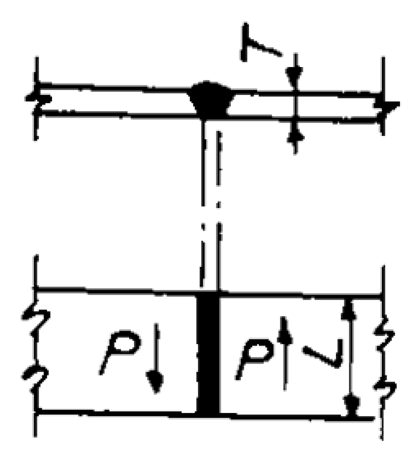
$P = 16\ T \times L$

FIG. D



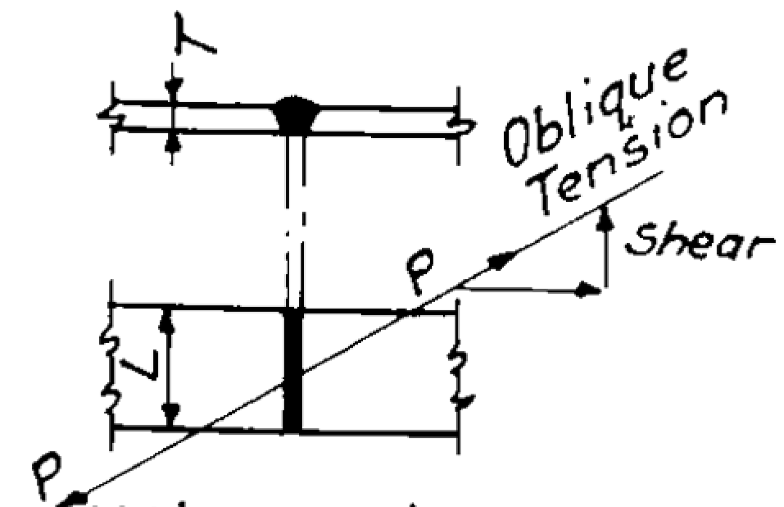
$P = 20\ T \times L$

FIG. E



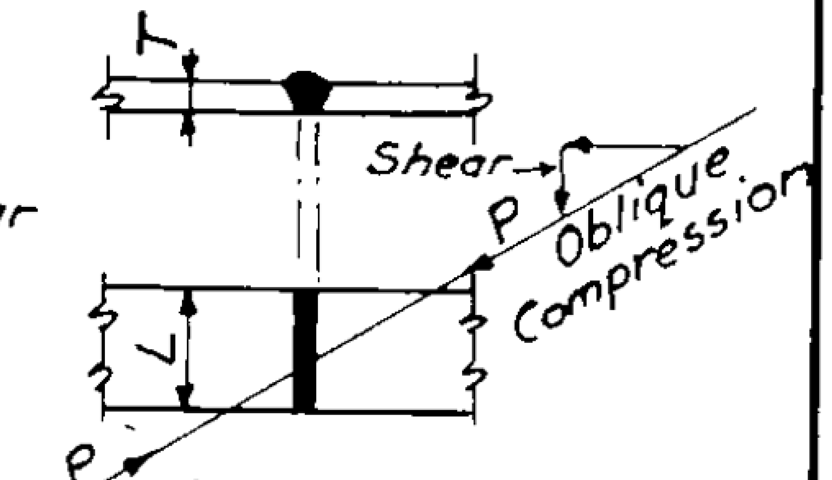
$P = 13\ T \times L$

FIG. F



Oblique Tension $\ngtr 16\ T \times L$
Shear $\ngtr 13.0\ T \times L$

FIG. G



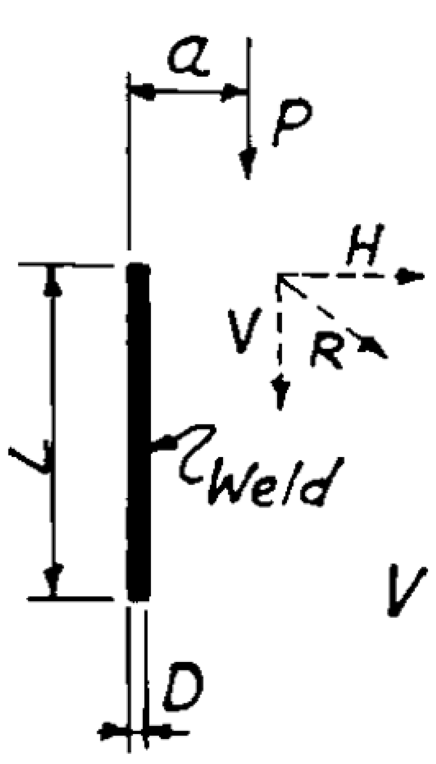
Oblique Comp. $= 20\ T \times L$.
Shear $\ngtr 13\ T \times L$.

FIG. H

DIRECT LOADS ON BUTT WELDS - FIG. D, E, F, G, H.

ECCENTRIC LOADING

MANY WELDED CONNECTIONS INVOLVE COMBINED STRESSES WHICH MAY BE SOLVED AS FOLLOWS:-



Given = $\begin{cases} P = 20{,}000 \text{ lbs.} \\ a = 2\tfrac{1}{2} \text{ inches} \\ L = 10 \text{ inches} \end{cases}$

Required: Size of weld.

V (Direct Load in lbs. per lineal inch) $= \dfrac{P}{L} = \dfrac{20{,}000}{10} = 2000\ \#/1''$

Moment $= P \times a = 20{,}000 \times 2\tfrac{1}{2} = 50{,}000$ in. lbs.

I_o - Polar Mom. $= \dfrac{L^3}{12} = 83.3$

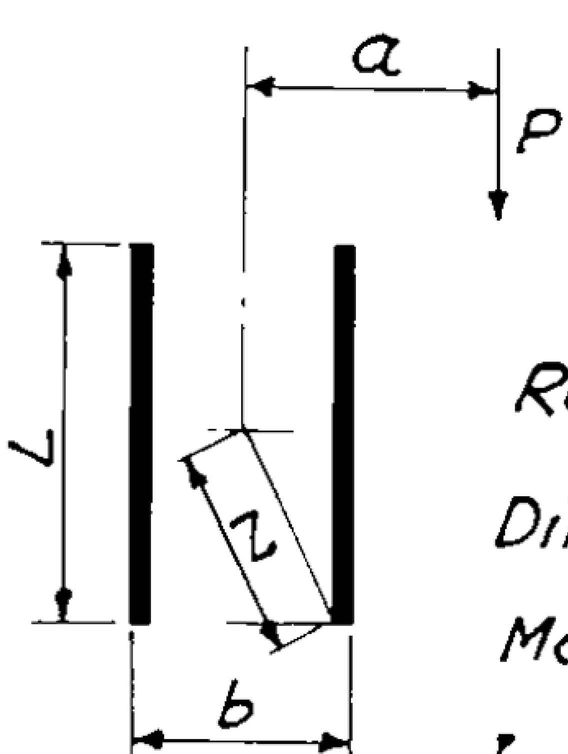
Max. $H = \dfrac{M}{I_o} \times \dfrac{L}{2} = 3000$ lbs.

Max. Stress $R = \sqrt{V^2 + H^2} = 3600$ lbs.

Using allowable shear 13,600 #/□".

For Fillet weld size $\dfrac{3600}{13600} \times \dfrac{1}{.707} = .375$

Use $\tfrac{3}{8}$" Weld.



Given: $\begin{cases} P = 24{,}000 \text{ lbs.} \\ a = 4 \text{ inches.} \\ L = 8 \text{ inches.} \\ b = 6 \text{ inches.} \\ Z = \sqrt{3^2+4^2} = 5 \text{ inches} \end{cases}$

Required: Size of welds.

Direct load $V = \dfrac{P}{2L} = \dfrac{24{,}000}{16} = 1500\ \#/1''$

Moment $= P \times a = 24{,}000 \times 4 = 96{,}000$ in. lbs.

I_o - Polar Mom. $= \dfrac{2L^3}{12} + \dfrac{Lb^2}{2} = 85 + 144 = 229.$

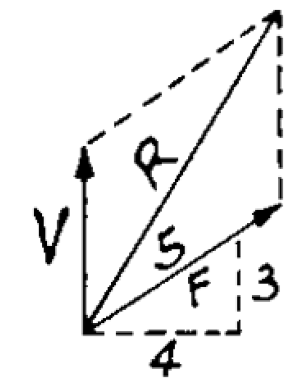
Mom. Stress $F = \dfrac{M \times Z}{I_o} = \dfrac{96{,}000}{229} \times 5 = 2100\#$

Resolving F: $FV = 2100 \times \tfrac{3}{5} = 1260\#$

$FH = 2100 \times \tfrac{4}{5} = 1680\#$

Total V Comp. $= 1500 + 1260 = 2760\#$ H Comp. $= 1680\#$

$R = \sqrt{2760^2 + 1680^2} = 3200\#$



GRAPHIC SOLUTION FOR R

Using allowable shear 13,600 #/□".

For Fillet Weld size $\dfrac{3200}{13{,}600} \times \dfrac{1}{.707} = .333$

Use $\tfrac{3}{8}$" Weld.

The above examples show simple cases of combined stress. The method of finding the stress due to moment by determining the Polar Moment of Inertia of weld group, solving for moment stress and combining with direct stress may be used for any weld pattern. Tables showing certain useful groups and formulas are shown on Page 1-96.

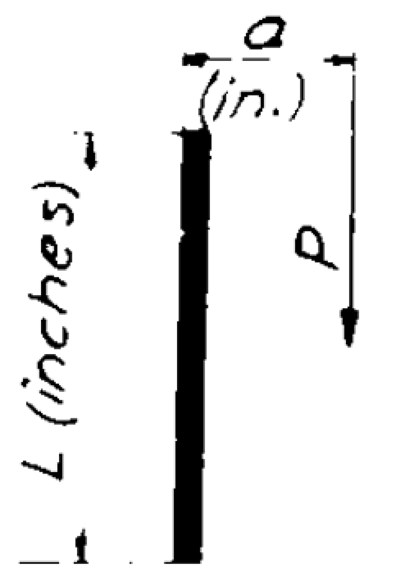
The above data are based on allowable unit stresses of A.I.S.C. Code 1942 as shown on Page 1-02.

STRUCTURAL - STEEL

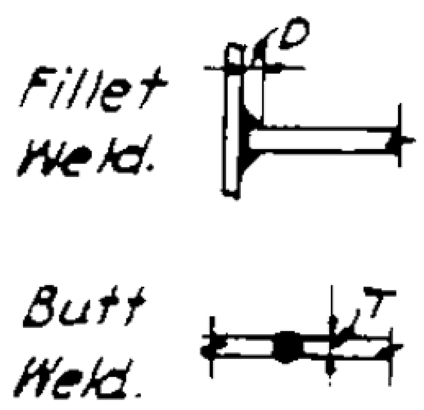
ALLOWABLE ECCENTRIC LOAD ON WELD GROUPS (IN KIPS.).

FORMULAS: $\frac{P}{D} = \frac{9.6\,L}{\sqrt{1+\left(\frac{6a}{L}\right)^2}}$; $\frac{P}{T} = \frac{16 \times L}{\sqrt{1+\left(\frac{6a}{L}\right)^2}}$

FOR SINGLE FILLET WELD. FOR BUTT WELD.



EXAMPLE:- (FILLET WELD)
Given: P (Load in kips) = 30
a (Moment arm) = 4"
D = Fillet weld size = 3/8"
Required: "L"
P/D = 80, From Table A L = 16"



EXAMPLE: (BUTT WELD)
Given: P = 35 ; a = 2"
T (Throat of weld) = 3/8"
P/T x 1/1.67 = 56; From Table A L = 10"
Check length for shear
L = P/13T = 7.2 - Use larger value.

Note: For two fillet welds, use 0.5 P/D.

TABLE A - VALUE OF P/D FOR SINGLE FILLET WELDS; VALUE OF P/T x 1/1.67 FOR BUTT WELDS

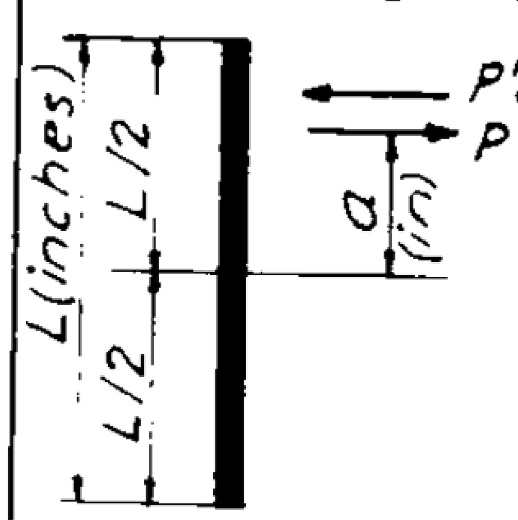
a \ L	2	4	6	8	10	12	14	16	18
0	19	38	57	76	96	115	134	153	173
½	11	31	51	72	91	111	131	151	170
1		21	41	61	82	102	123	143	163
1½		15	32	51	71	92	113	133	154
2			25	42	61	81	102	123	144
2½			21	36	53	72	92	112	133
3			18	31	46	64	82	101	122
4				24	37	51	68	85	103
5				19	30	42	56	72	88
6					25	36	49	62	77

FORMULAS:

$\frac{P}{D} = \frac{9.6L}{1+\frac{6a}{L}}$; Tension: $\frac{P}{T} = \frac{16\,L}{1+6a/L}$

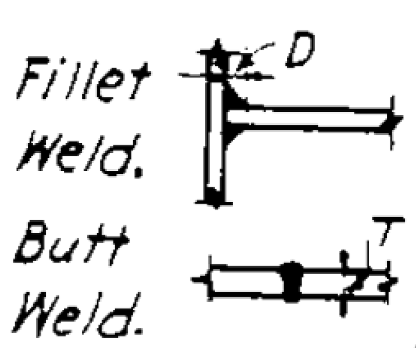
Comp.: $\frac{P'}{T} = \frac{20\,L}{1+6a/L}$ for $a \leq 2.33L$

FOR SINGLE FILLET WELD. FOR BUTT WELD.



EXAMPLE : (FILLET WELD)
Given: P = 25 ; a = 3"; D = 3/8": Req. "L"
P/D = 67; From Table B, L = 16"

EXAMPLE: (BUTT WELD IN TENSION)
Given: P = 25; a = 2"; T = 3/8": Req.: "L"
P/T x 1/1.67 = 40 - From Table B, L = 10."



EXAMPLE: (BUTT WELD IN COMP.)
Given: P = 25; a = 1½"; T = 3/8". Req.: "L"
P/T x 1/2.08 = 32 - From Table B, L = 8"

Note: For two fillet welds, use 0.5 P/D.

TABLE B - VALUE OF P/D FOR SINGLE FILLET WELDS; VALUE OF P/T x 1/1.67 FOR BUTT WELDS IN TENSION; VALUE OF P/T x 1/2.08 FOR BUTT WELDS IN COMP.

a \ L	2	4	6	8	10	12	14	16	18
0	19	38	57	76	96	115	134	153	173
½	7	21	38	56	74	92	110	129	148
1		15	29	44	60	76	94	111	129
1½			23	36	50	66	81	98	115
2				30	43	57	72	87	103
2½					38	51	65	79	94
3					34	46	58	72	86
4						38	49	61	74
5							42	53	64

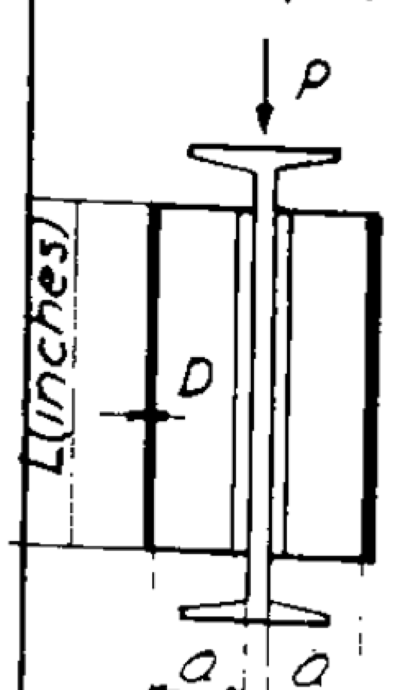
TABLE C - BEAM CONNECTIONS - OUTSTANDING LEGS.

FORMULA:

$P = \frac{19.2\,D \times L}{\sqrt{1+(3\,a/L)^2}}$

VALUE OF P IN KIPS FOR "a" = 3"

L \ D	1/4"	3/8"	1/2"	L \ D	1/4"	3/8"	1/2"
6	16	24	32	18	77	115	154
8	25	38	51	21	92	138	184
10	35	54	72	24	107	162	214
12	46	69	92	27	123	184	246
15	61	91	122	30	138	206	276

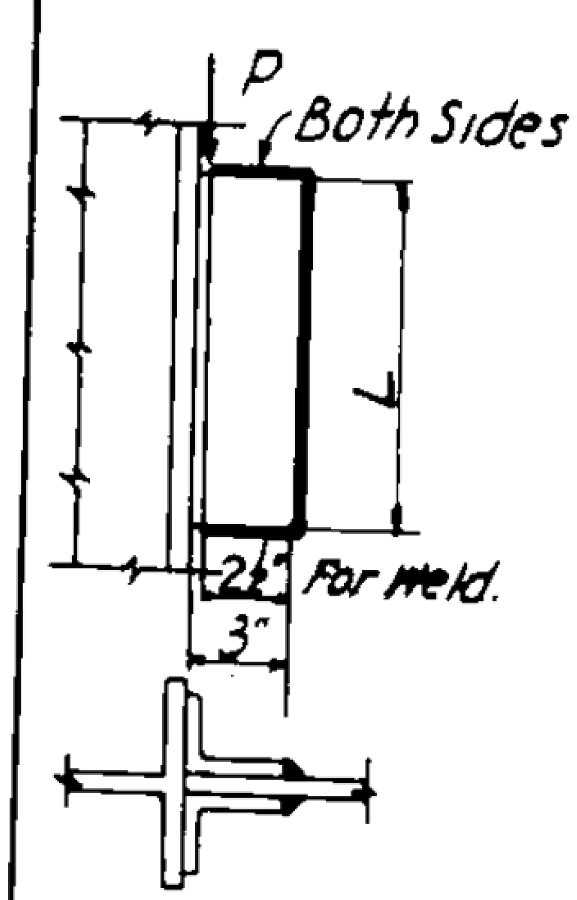


EXAMPLE: Given: L = 10"; D = 3/8"
Required P
From Table C, P = 54 kips.

TABLE D - BEAM CONNECTIONS - WEB.

VALUE OF P IN KIPS.

Values in Table D calculated using method on p. 1-95



L \ D	1/4"	3/8"	1/2"	L \ D	1/4"	3/8"	1/2"
6	25	37	50	18	84	126	168
8	34	51	68	21	99	149	198
10	44	66	88	24	114	171	228
12	54	81	108	27	130	193	260
15	69	104	138	30	145	215	289

Note: Investigate beam web for shear.

EXAMPLE: Given: L = 10"; D = 3/8"
Required: P
From Table D, P = 66 kips.

The above Tables and formulas are based on method shown on p. 1-95 except Table C, where formula used is from Arc Welded Steel Frame Structures, by Gilbert D. Fish.
All values shown are based on the allowable stresses of the A.I.S.C. Code 1942 as shown on p. 1-02.

STRUCTURAL - STEEL

WELDING DETAILS

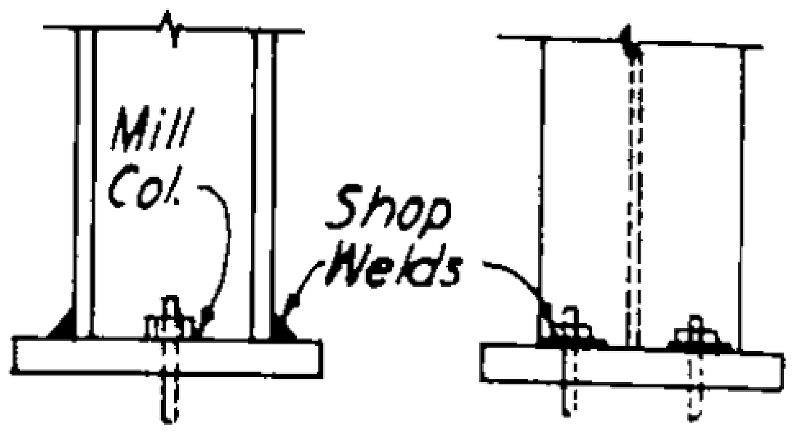


FIG. A

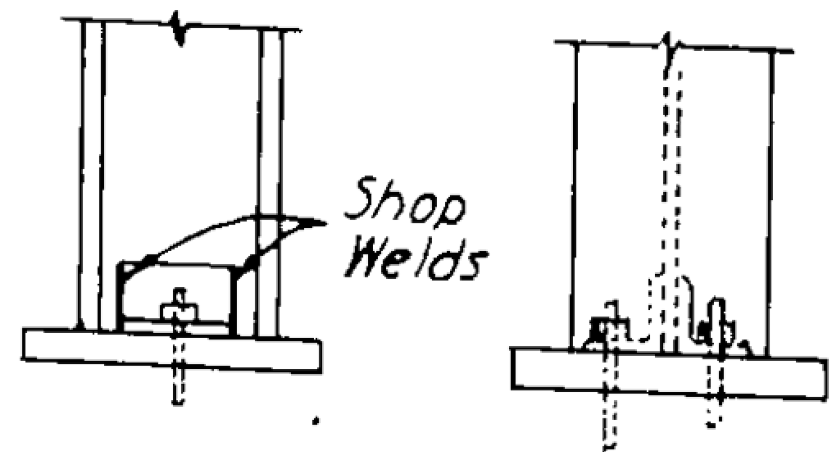


FIG. B

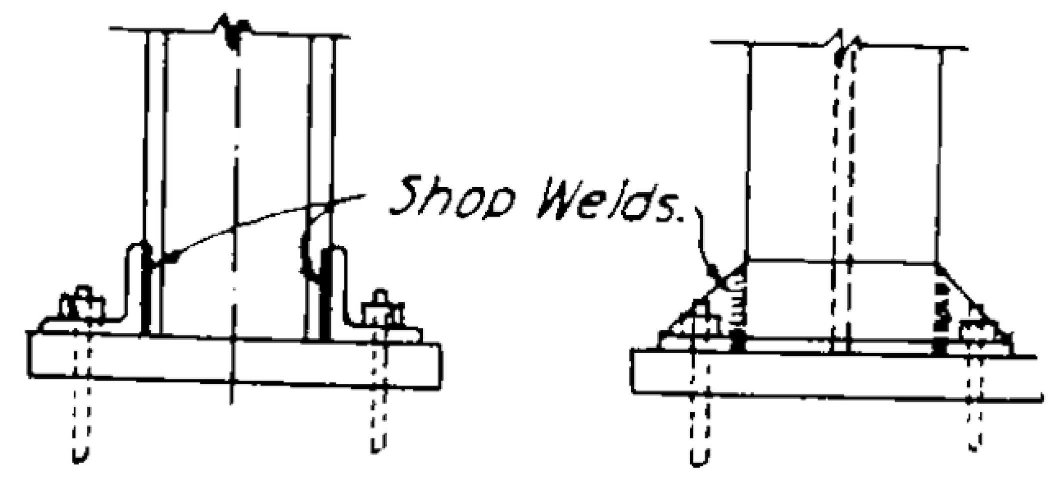


FIG. C

COLUMN BASE DETAILS

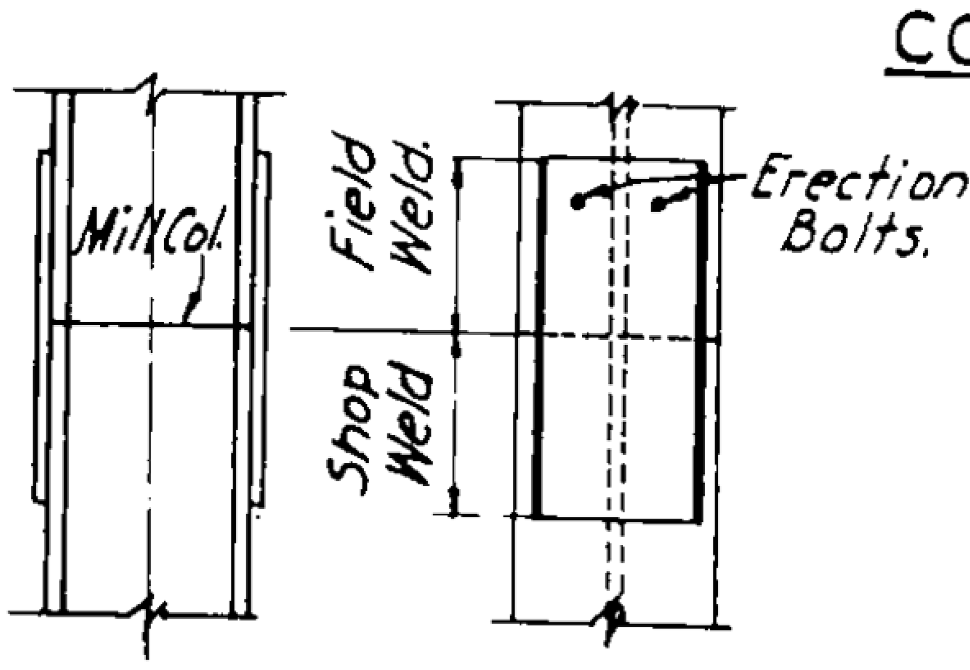


FIG. D

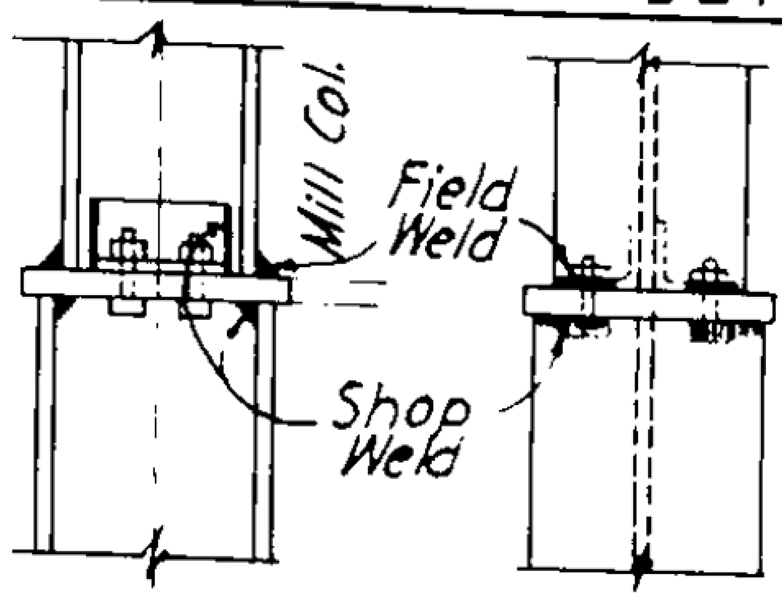


FIG. E (PREFERRED)

COLUMN SPLICES

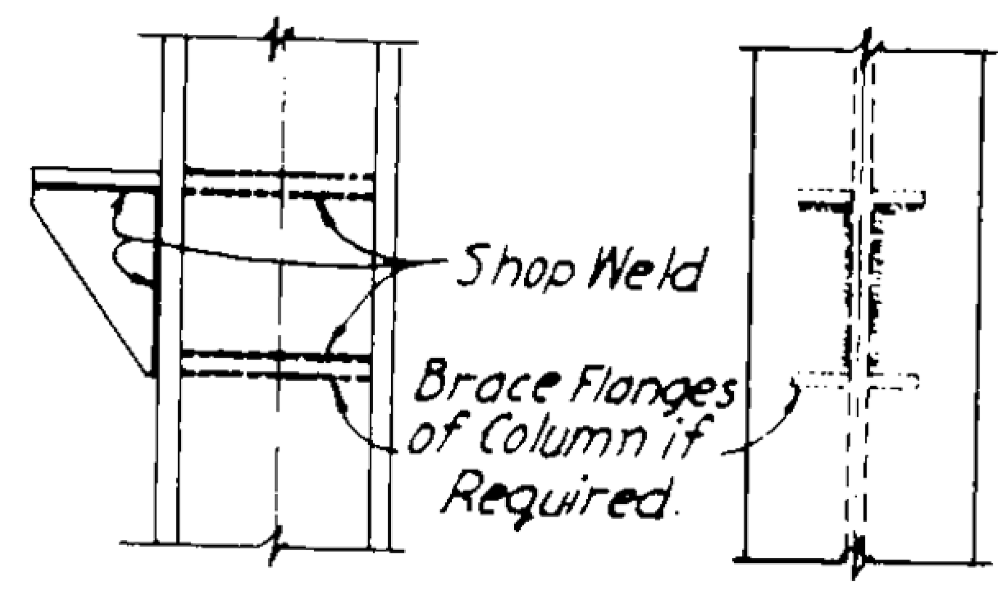


FIG. F

COLUMN BRACKET

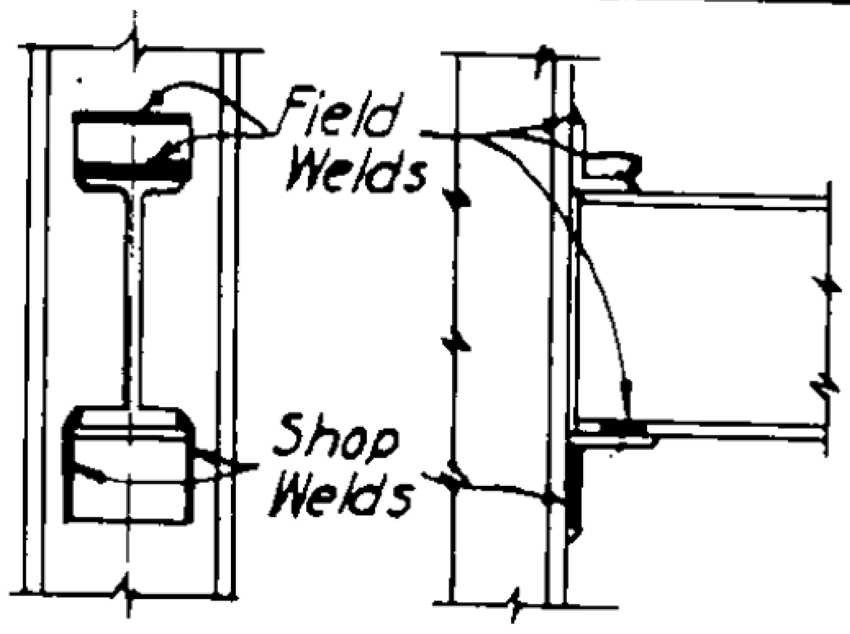


FIG. G

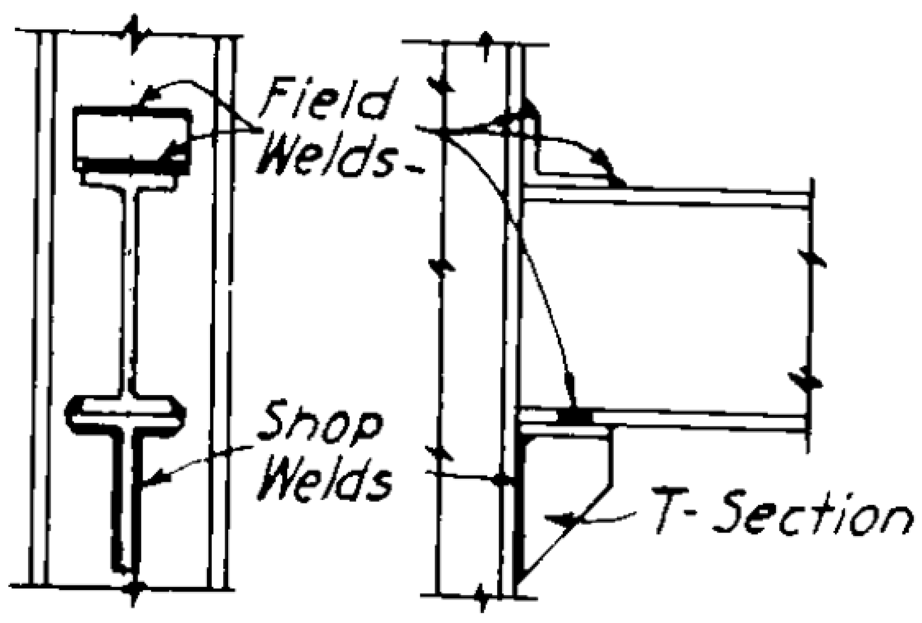


FIG. H

COLUMN WEB CONNECTIONS

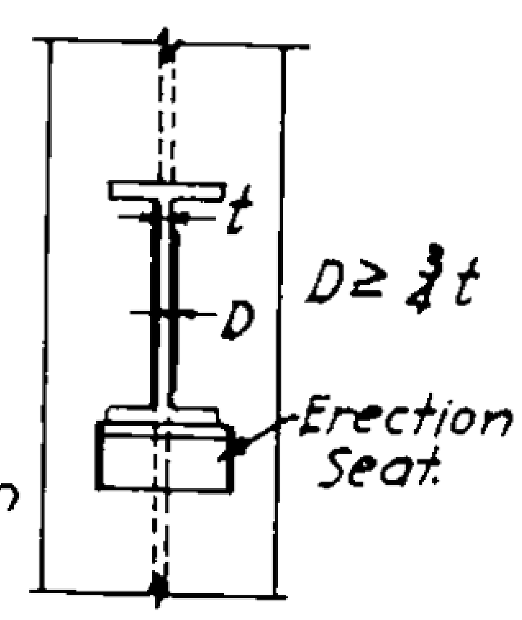
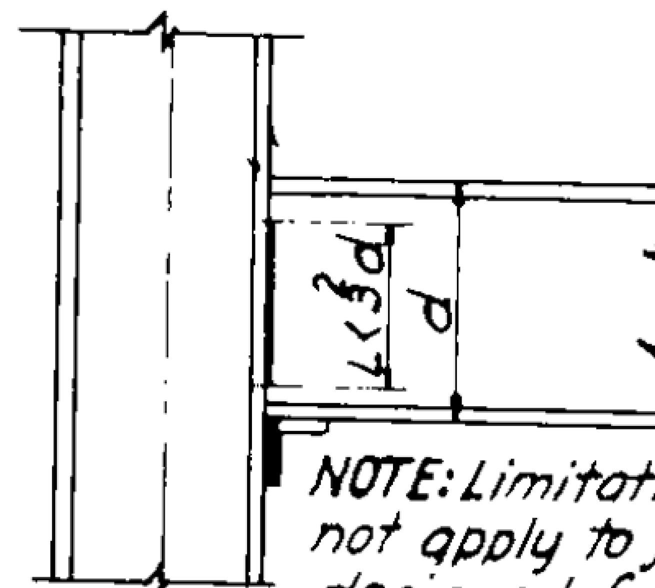


FIG. K



NOTE: Limitations do not apply to joints designed for full continuity moment.

COLUMN FLANGE CONNECTIONS

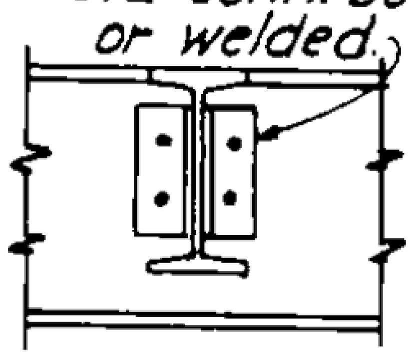


FIG. L

BEAM TO BEAM CONN.

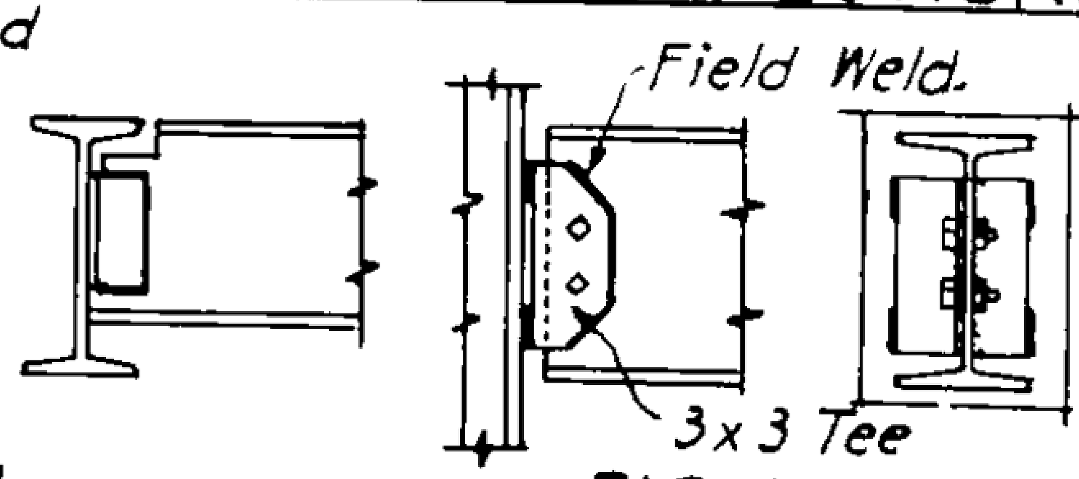


FIG. M

TEE CONN. BEAM TO COL.

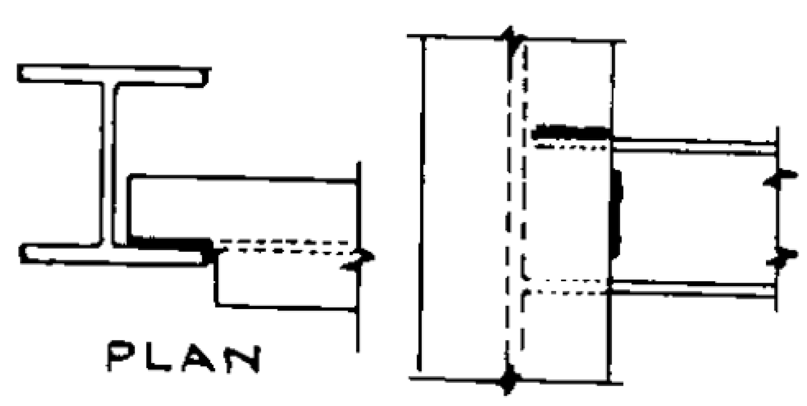


FIG. N

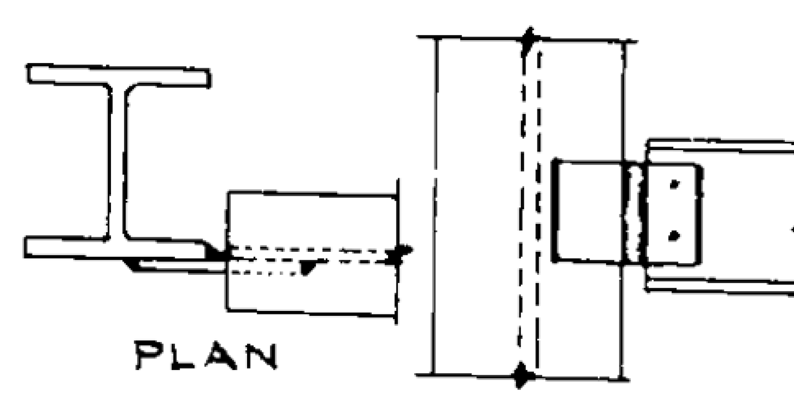
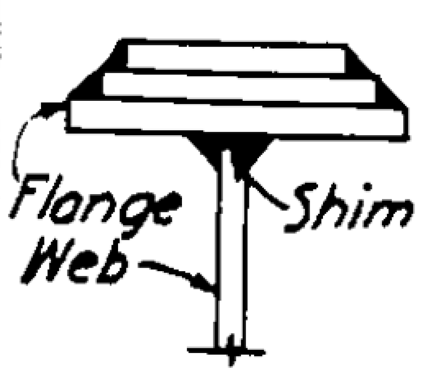


FIG. P

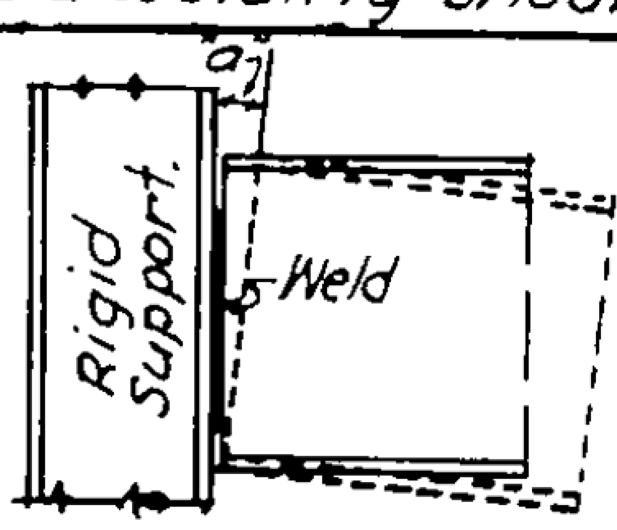
SPANDREL BEAM CONN. TO COLUMNS.

NOTE:- The above connections have proved satisfactory in practice. For cases of questionable practice, see examples given below. For dynamic loading, fatigue and reversal of stresses, see bridge practice of American Welding Society. Overhead welding should be avoided in design where possible.



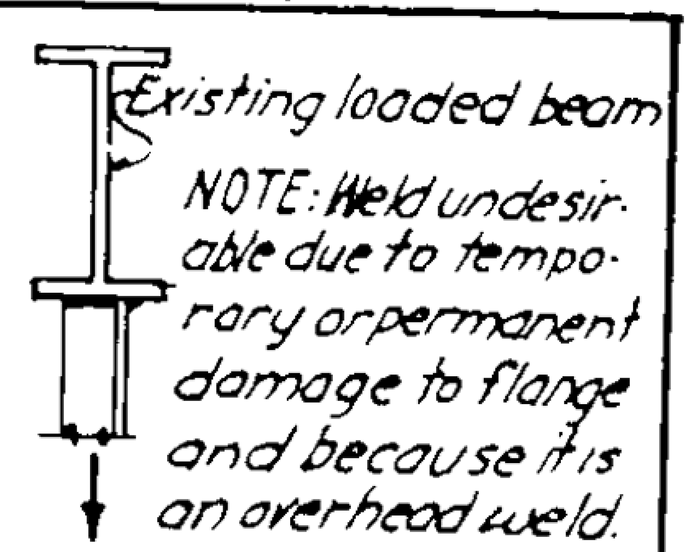
NOTE: Heavy flange cools weld rapidly. Tight bearing does not allow web to move in toward flange in cooling of weld, causing possible weld fracture. Precaution: Provide shims between flange and web while welding.

TYPICAL GIRDER FLANGE.



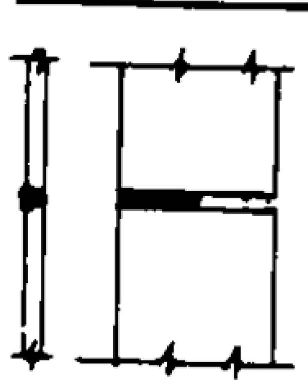
NOTE: Direct connection to rigid support will be subject to bending strain having an angle "a" due to rotation at end of beam. Precaution: Keep welds within limits shown in Fig. K above.

RIGID CONNECTION.



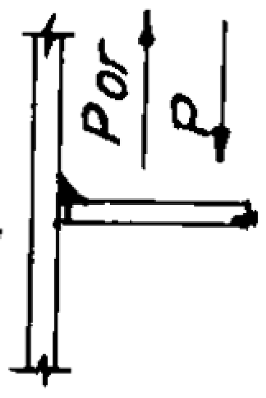
NOTE: Weld undesirable due to temporary or permanent damage to flange and because it is an overhead weld.

INCORRECT.



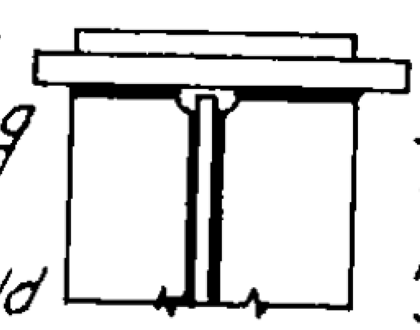
NOTE: Butt weld should be made clear across joint in thin layers. If weld is made as shown, final weld may crack due to restraint against shrinkage by the initial weld.

BUTT JOINT.



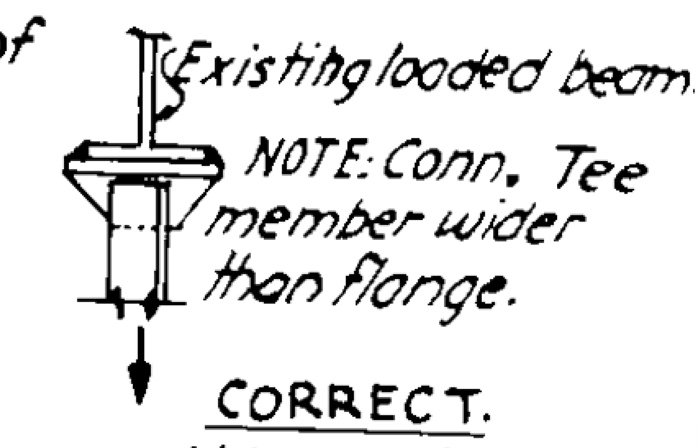
NOTE: Fillet weld subject to bending about longitudinal axis in either direction should not be used.

UNSAFE FILLET WELD.



NOTE: Snipping of stiffeners and other similar procedure are suggested to avoid biaxial rigidity.

SNIPPING.



NOTE: Conn. Tee member wider than flange.

CORRECT.

HANGER.

RED LIGHTS IN WELDING.

STRUCTURAL - WOOD

WOOD JOISTS

SAFE LOAD CURVES

TABLE A - NET SECTION MODULI = $\frac{bd^2}{6}$

Nom. Size	Actual Size	S	Nom. Size	Actual Size	S	Nom. Size	Actual Size	S	Nom. Size	Actual Size	S	Nom. Size	Actual Size	S	Nom. Size	Actual Size	S
2 x 4	1 5/8 x 3 5/8	3.56	3 x 4	2 5/8 x 3 5/8	5.75	4 x 4	3 5/8 x 3 5/8	7.94	6 x 6	5 1/2 x 5 1/2	27.7	8 x 8	7 1/2 x 7 1/2	70.3	10 x 10	9 1/2 x 9 1/2	143
2 x 6	1 5/8 x 5 5/8	8.57	3 x 6	2 5/8 x 5 5/8	13.8	4 x 6	3 5/8 x 5 5/8	19.1	6 x 8	5 1/2 x 7 1/2	51.6	8 x 10	7 1/2 x 9 1/2	113	10 x 12	9 1/2 x 11 1/2	209
2 x 8	1 5/8 x 7 1/2	15.3	3 x 8	2 5/8 x 7 1/2	24.6	4 x 8	3 5/8 x 7 1/2	34.0	6 x 10	5 1/2 x 9 1/2	82.7	8 x 12	7 1/2 x 11 1/2	165	10 x 14	9 1/2 x 13 1/2	289
2 x 10	1 5/8 x 9 1/2	24.4	3 x 10	2 5/8 x 9 1/2	39.5	4 x 10	3 5/8 x 9 1/2	54.5	6 x 12	5 1/2 x 11 1/2	121	8 x 14	7 1/2 x 13 1/2	228	10 x 16	9 1/2 x 15 1/2	380
2 x 12	1 5/8 x 11 1/2	35.8	3 x 12	2 5/8 x 11 1/2	57.9	4 x 12	3 5/8 x 11 1/2	79.9	6 x 14	5 1/2 x 13 1/2	167	8 x 16	7 1/2 x 15 1/2	300	10 x 18	9 1/2 x 17 1/2	485
2 x 14	1 5/8 x 13 1/2	49.4	3 x 14	2 5/8 x 13 1/2	79.7	4 x 14	3 5/8 x 13 1/2	110.0	6 x 16	5 1/2 x 15 1/2	220	8 x 18	7 1/2 x 17 1/2	383	10 x 20	9 1/2 x 19 1/2	602

FIG. B 2" JOISTS

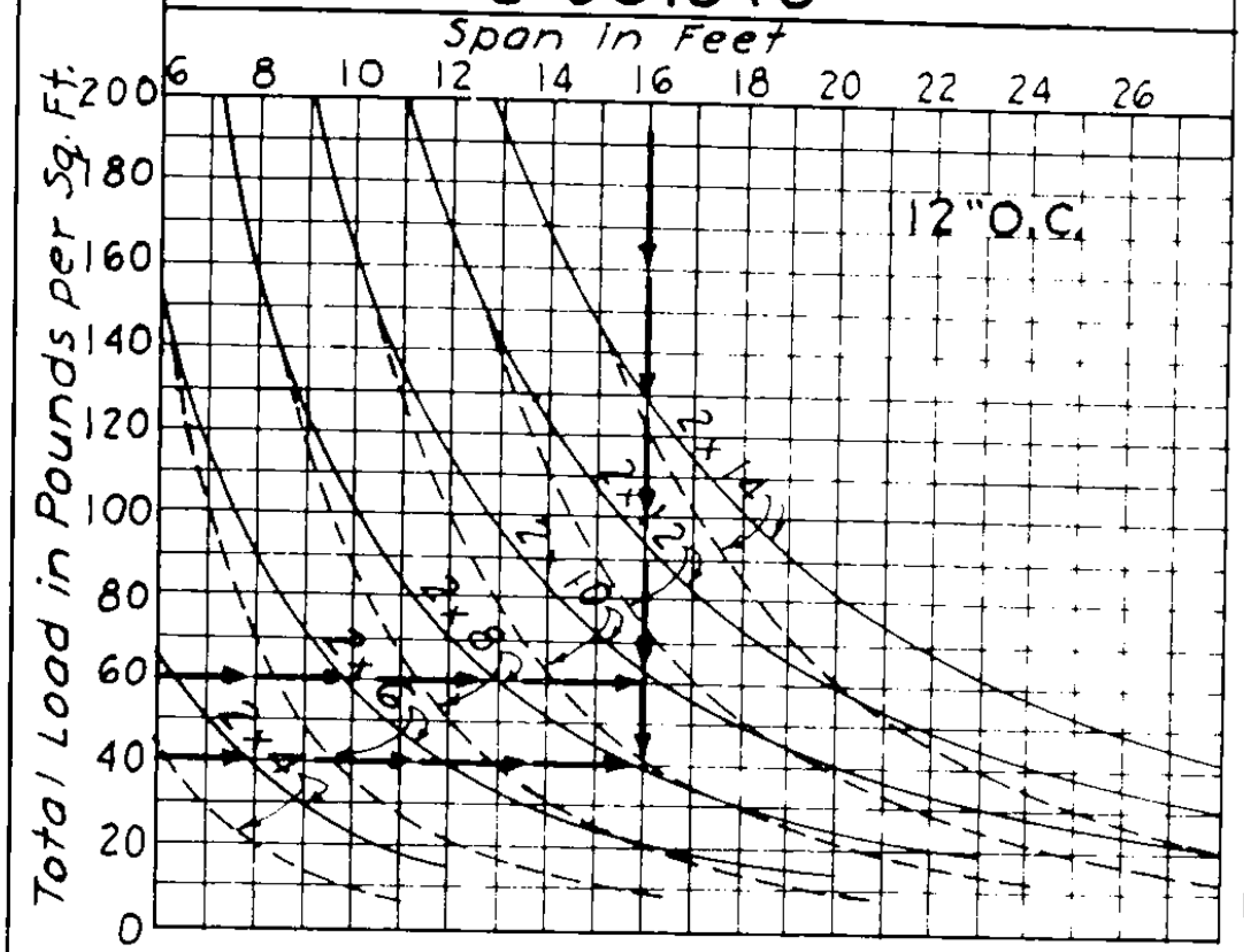
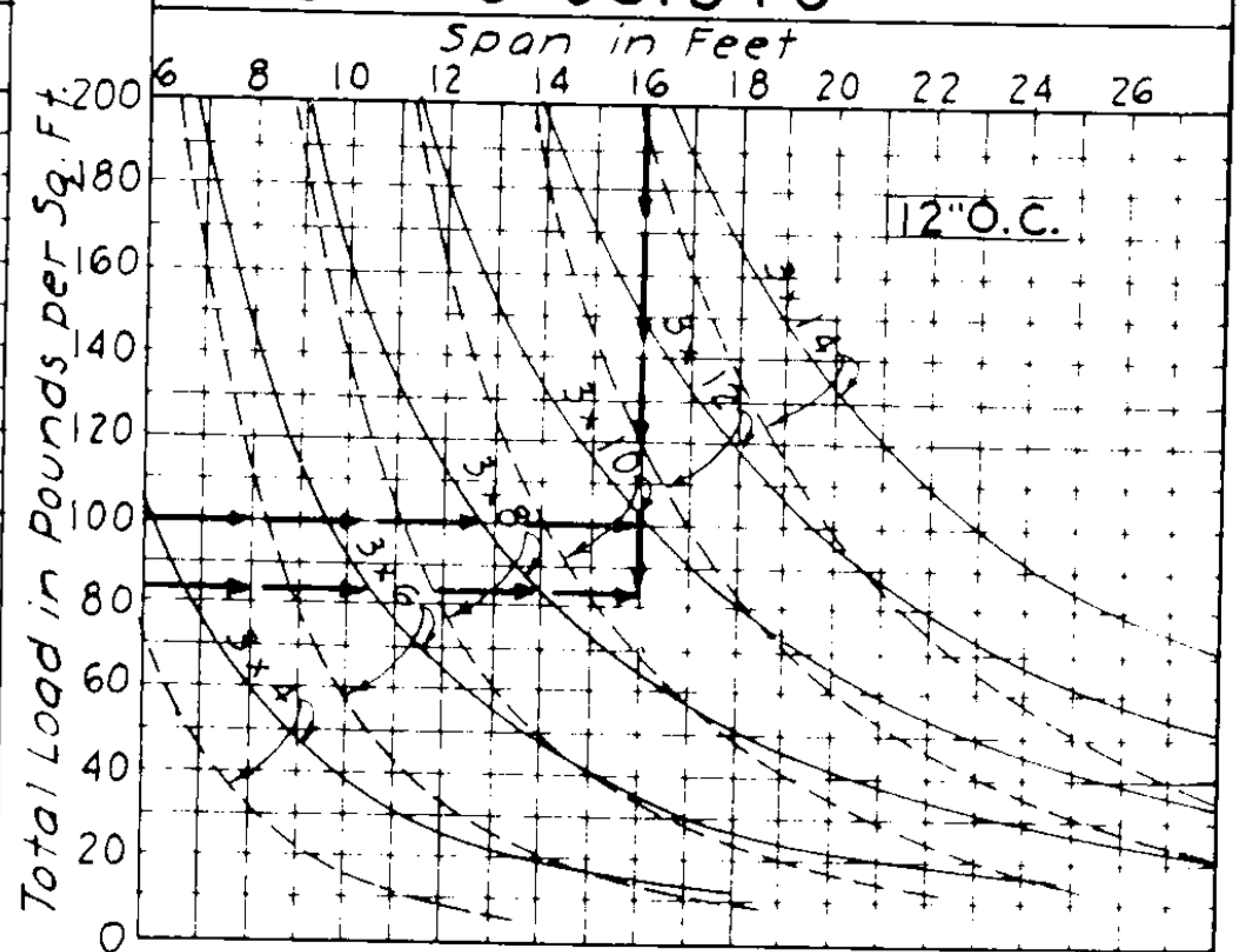


FIG. C 3" JOISTS



Solid Curves show span and load of which bending stress in joists is 1000 lbs. per sq. in.
Dashed Curves show span and load which will cause a deflection of 1/360 of the span based on Modulus of Elasticity of E = 1,000,000.
Bending Stress governs the size of joists unless plastered ceilings or specifications call for limited deflection. All joists with loads greater than shown in Fig B & C must be checked for hor. shear.
For allowable working stresses and moduli of elasticity *see pages 1-03 & 1-04.*

__Example 1__:- __Given__: Live Load (L.L.) = 40 Lbs. per Sq. Ft., Dead Load (D.L.) = 20 Lbs. per Sq. Ft., Span (L) = 16'-0", Stress (f) = 1000 Lbs. per Sq. In., E = 1,000,000 Lbs.

__Required__: Size and spacing of 2" joists.

__Solution__: Enter Fig. B at 16' span and 60 Lbs. total load and find intersection below Solid Curve of 2x10 - 12" o.c. ∴ 2x10 - 12" o.c. are good for bending.

Check deflection for live load of 40 Lbs. Enter Fig. B at 16' span and 40 Lbs. load and find intersection below dashed curve of 2x10-12" o.c. ∴ 2x10-12" o.c. are good for deflection.

If spacing of 16" o.c. is desired, enter Fig. B with load of $60 \times \frac{16}{12} = 80$ Lbs. for bending, and load of $40 \times \frac{16}{12} = 53$ Lbs. for deflection. Proceed same as above.

__Example 2__:- __Given__ L.L. = 100 Lbs. per Sq. Ft., D.L. = 20 Lbs. per Sq. Ft., Span = 16'-0", working stress = 1200 lbs/□" and E = 1,200,000

__Required__: Size and spacing of 3" joists.

__Solution__: Decrease total load in proportion to stresses - $W = 120 \times \frac{1000}{1200} = 100$ Lbs. per Sq. Ft. Enter Fig. C at 16' span and 100 Lbs. load and find intersection below Solid Curve for 3x10 - 12" o.c. ∴ 3x10 - 12" o.c. are good for bending.

Check deflection - decrease deflection for live load in proportion to E, or $100 \times \frac{1,000,000}{1,200,000} = 83$ Lbs. Enter Fig. C at 16' span and 83 Lbs. - find intersection above dashed curve of 3x10 ∴ Use 3x12 if deflection has to be less than 1/360 and if 12" o.c. desired.

If 16" o.c. spacing is desired, decrease load as above and proceed as in Example 1.

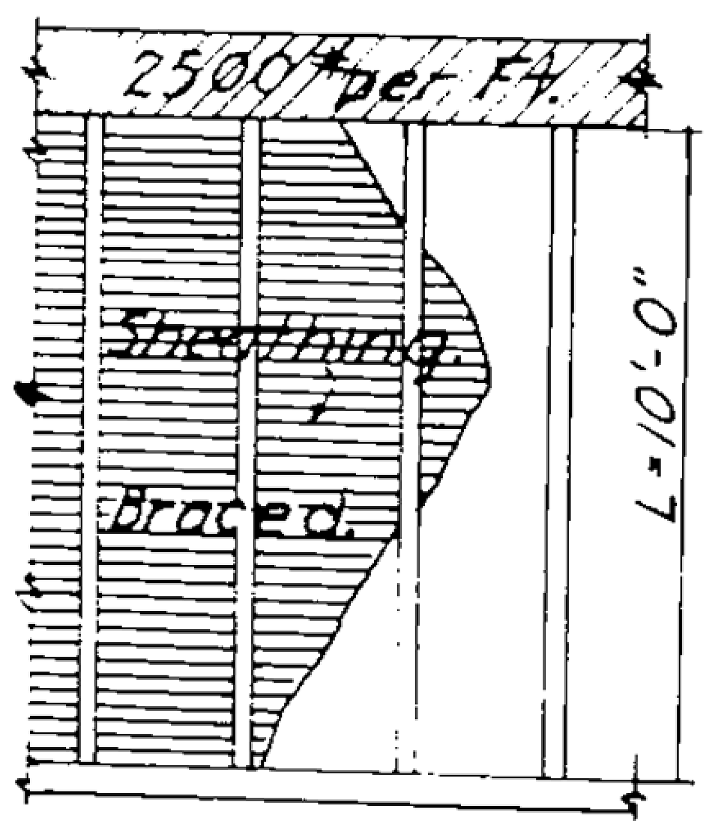
STRUCTURAL - WOOD

TABLE A - STUD PARTITIONS.
LOADS IN KIPS PER LINEAR FOOT.

BASED ON TIMBER WITH:
E = 1,600,000#/□"; COMP. STRESS = 900#/□"

HEIGHT "L" IN FT. / NO. OF ROWS OF BRIDGING	2x4		2x6			2x8				3x4		3x6			3x8			4x4
SIZE OF STUDS - 16" O.C.	1	2*	1	2	3*	1	2	3	4*	0	1*	0	1	2*	0	1	2*	0*
7 - 0	2.84	3.25	4.40	5.80	5.98	5.88	7.75	8.07	8.15	3.06	5.26	4.75	9.60	9.66	6.34	12.79	13.18	7.25
8 - 0	2.20	2.67	3.41	5.56	5.84	4.56	7.44	7.97	8.09	2.32	4.44	3.61	9.30	9.43	4.80	12.40	13.08	5.95
9 - 0	1.74	2.18	2.70	5.23	5.64	3.60	7.00	7.84	8.01	1.86	3.53	2.89	8.86	9.12	3.85	11.81	12.95	4.86
10 - 0	1.41	1.77	2.18	4.74	5.37	2.92	6.33	7.63	7.89	1.48	2.86	2.30	8.27	8.68	3.06	11.02	12.74	3.94
11 - 0	1.18	1.46	1.83	4.13	4.99	2.44	5.45	7.35	7.74	1.25	2.36	1.94	7.46	8.07	2.59	9.95	12.50	3.26
12 - 0	0.98	1.23	1.52	3.42	4.51	2.08	4.57	6.96	7.53		1.99		6.45	7.29		8.60	12.17	2.74
13 - 0	0.84	1.05	1.30	2.93	3.92	1.74	3.92	6.54	7.25		1.70		5.53	6.17		7.37	11.71	2.34
14 - 0		0.84		2.53	3.36		3.36	5.92	6.93		1.36		4.75	5.43		6.33	11.20	2.01
15 - 0		0.79		2.20	2.93		2.92	5.34	6.52		1.28		4.12	4.73		5.50	10.55	1.76
16 - 0				1.93	2.57		2.58	4.60	6.00				3.74	4.15		4.98	9.70	

*Note: Use values in this line either for given rows of bridging or for no rows of bridging where studs are braced laterally in weak direction by sheathing and plaster, or similar stiff materials.
For spacing other than 16" o.c. - Multiply Table values by 16/spacing in inches.
Values given are based on column formulas recommended by Forest Products Laboratory, Forest Service, Department of Agriculture.
Studs must be checked for wind and any other special conditions.



EXAMPLE #1

Given: Height of partition = 10'-0" - Braced laterally.
Load per foot = 2500#

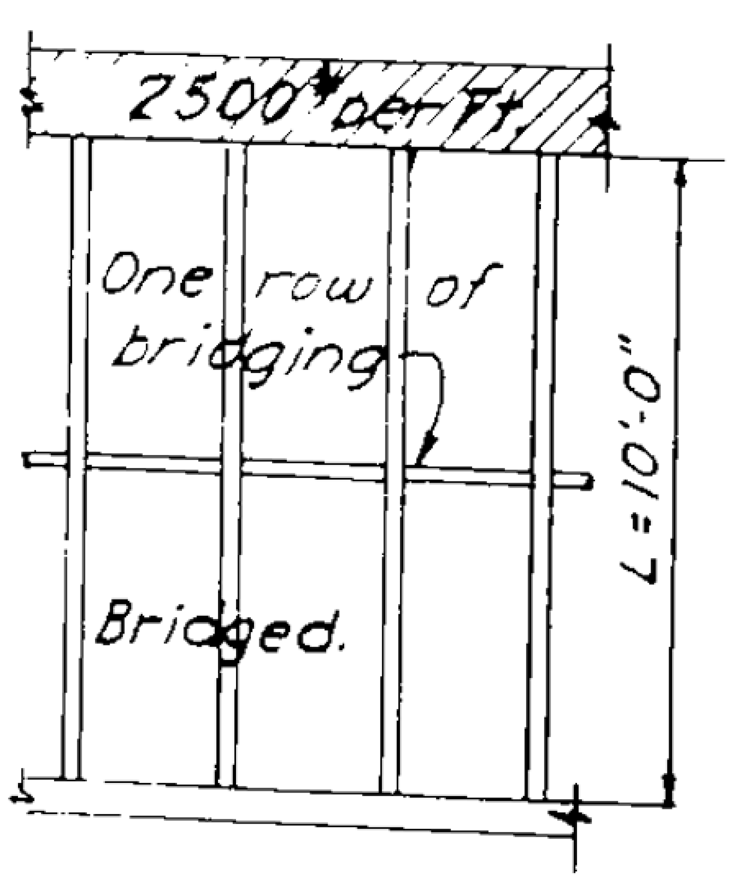
Required: Size and spacing of studs.

Solution: From Table A -

Using 2x4 studs - spacing = $\frac{1770}{2500} \times 16$ = 11.3" Max.

Using 2x6 studs - spacing = $\frac{5370}{2500} \times 16$ = 34.4" Max.

Using 3x4 studs - spacing = $\frac{2860}{2500} \times 16$ = 18.3" Max.



EXAMPLE #2

Given: Height of partition = 10'-0" - Braced laterally with 1 row of bridging; Load per foot = 2500#

Required: Size and spacing of studs.

Solution: From Table A -

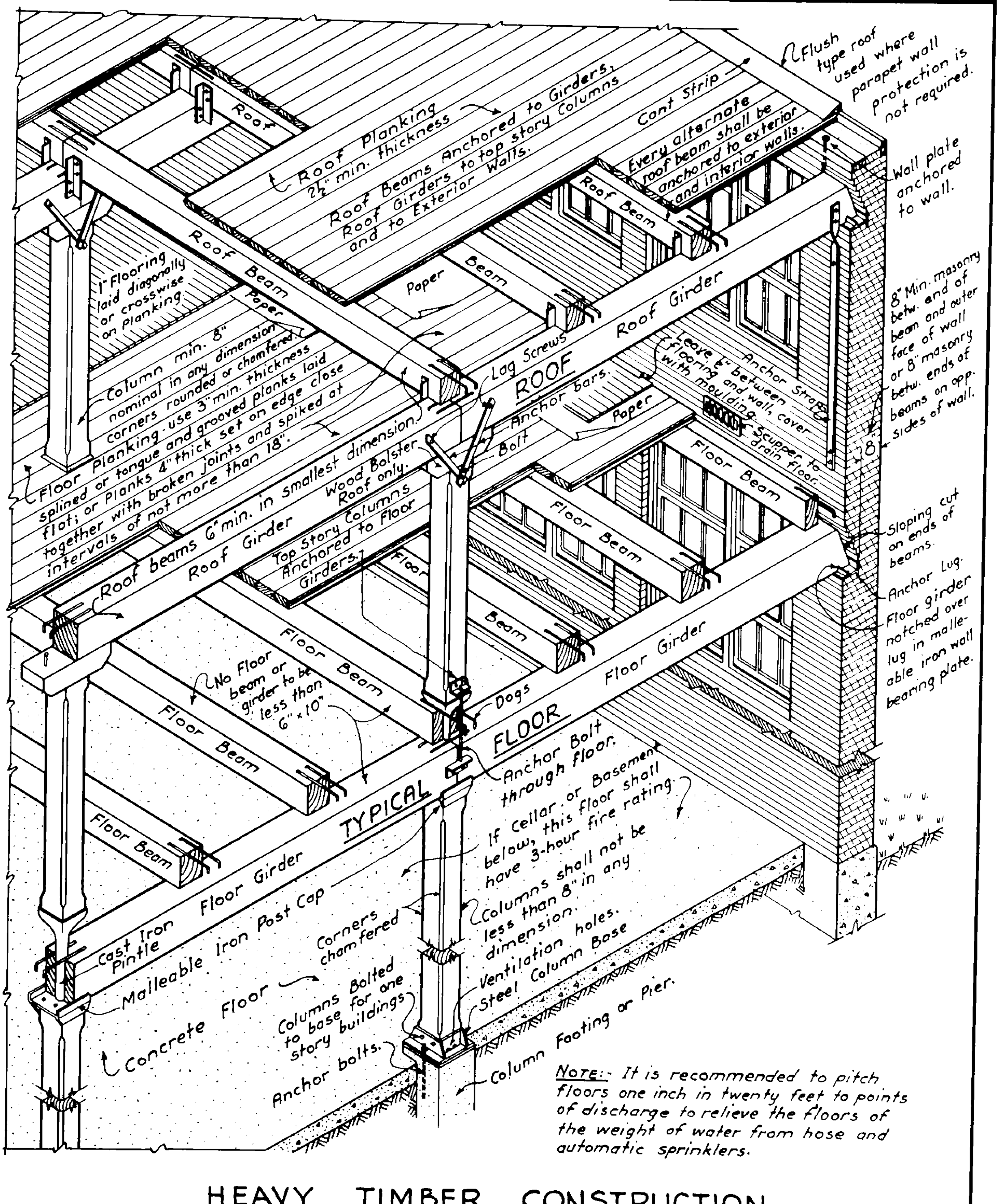
Using 2x4 studs - spacing = $\frac{1410}{2500} \times 16$ = 9" Max.

Using 2x6 studs - spacing = $\frac{2180}{2500} \times 16$ = 14" Max.

Using 2x8 studs - spacing = $\frac{2920}{2500} \times 16$ = 18.7" Max.

Using 3x4 studs - spacing = $\frac{2860}{2500} \times 16$ = 18.3" Max.

STRUCTURAL - WOOD



HEAVY TIMBER CONSTRUCTION

ALSO KNOWN AS "SLOW-BURNING MILL CONSTRUCTION"

Adapted from Natl. Lumber Mfrs. Assoc. Bulletin No. 4.

STRUCTURAL - WOOD

TABLE A - LATERAL RESISTANCE OF WIRE NAILS IN POUNDS.*

SIZE OF NAIL IN PENNYWEIGHTS.	SOFTWOODS: CEDAR - NORTH. WHITE. SOUTH. WHITE. FIR - BALSAM. COMMERCIAL WHITE. HEMLOCK (EASTERN). PINE - LODGEPOLE, PONDEROSA, SUGAR, NORTH WHITE, WESTERN WHITE. SPRUCE - ENGELMANN, RED, SITKA & WHITE. $P=1080D^{3/2}$	SOFTWOODS: CEDAR - ALASKA, INCENSE, PORT ORFORD, WESTERN RED, EASTERN RED. CYPRESS (SOUTH.) DOUGLAS FIR - ROCKY MT. REGION. HEMLOCK (WESTERN). PINE (NORWAY). REDWOOD. TAMARACK. $P=1350D^{3/2}$	SOFTWOODS: DOUGLAS FIR - COAST REGION. LARCH (WESTERN). PINE (SOUTH. YELLOW). $P=1650D^{3/2}$	MIN. PENETRATION.	HARDWOODS: ASPEN & LARGETOOTH ASPEN. BASSWOOD. BUTTERNUT. COTTONWOOD - BLACK, EASTERN. POPLAR. $P=1080D^{3/2}$	HARDWOODS: ALDER (RED). ASH (BLACK). BIRCH (PAPER). ELM (AMERICAN & SLIPPERY). GUM (RED & BLACK TUPELO). HACKBERRY. MAGNOLIA (CUCUMBER, EVERGREEN). MAPLE (BIG LEAF, SOFT, RED & SILVER). SUGARBERRY. SYCAMORE. $P=1500D^{3/2}$	HARDWOODS: ASH (COMMERCIAL WHITE) OREGON. BEECH. BIRCH (SWEET & YELLOW). CHERRY (BLACK). ELM (ROCK). HICKORY (TRUE & PECAN). HONEY LOCUST. LOCUST (BLACK). MAPLE (HARD), BLACK & SUGAR. OAK (RED & WHITE). WALNUT. $P=2040D^{3/2}$	MIN. PENETRATION.
4	34	42	51	1"	34	47	64	3/4"
6	41	51	63	1 3/8"	41	57	77	1"
8	51	64	78	1 5/8"	51	71	96	1 1/4"
10	62	77	94	2"	62	86	117	1 1/2"
12	62	77	94	2 1/8"	62	86	117	1 5/8"
16	70	88	108	2 1/4"	70	97	132	1 3/4"
20	91	113	138	2 5/8"	91	126	172	2"
30	102	127	155	3"	102	141	193	2 1/4"
40	115	146	176	3 1/4"	115	159	217	2 1/2"
50	130	163	198	3 5/8"	130	180	246	2 3/4"
60	146	182	222	4"	146	202	275	3"

*This Table is based on seasoned wood and a safety factor of about 5.
NOTE: Increase values 25% where metal side plates are used.
Decrease values 33% when nails are driven in end grain.
Decrease values 25% for side grain of unseasoned wood which will remain wet, or will be loaded before seasoning. P = Load in pounds; D = Diameter of nail in inches.

TABLE B - RESISTANCE OF WIRE NAILS TO WITHDRAWAL FROM SIDE GRAIN IN POUNDS PER INCH OF PENETRATION (IN MAIN MEMBER).

SPECIES / PENNYWEIGHT	4	6	8	10	12	16	20	30	40	50	60
BIRCH - YELLOW & SWEET.	53	61	72	80	80	89	104	113	122	133	144
DOUGLAS FIR.	25	29	34	38	38	42	49	53	58	62	67
MAPLE - SUGAR.	52	60	68	78	78	85	101	109	119	128	138
OAK - RED & WHITE.	53	61	72	80	80	89	104	113	122	133	144
PINE - LONGLEAF.	36	41	47	54	54	56	60	66	71	77	83
PINE - NORTH. WHITE.	14	16	18	20	20	23	26	29	31	34	36
PINE - PONDEROSA.	16	18	20	23	23	25	30	32	36	38	42
PINE - SHORTLEAF.	29	34	38	43	43	46	49	53	58	62	68
REDWOOD.	16	18	20	23	23	25	30	32	36	38	42
SPRUCE - SITKA.	16	17	20	23	23	25	30	32	35	37	41

When driven in unseasoned wood which will season subsequently under load, use 25% of values.
Do not design for withdrawal from end grain.

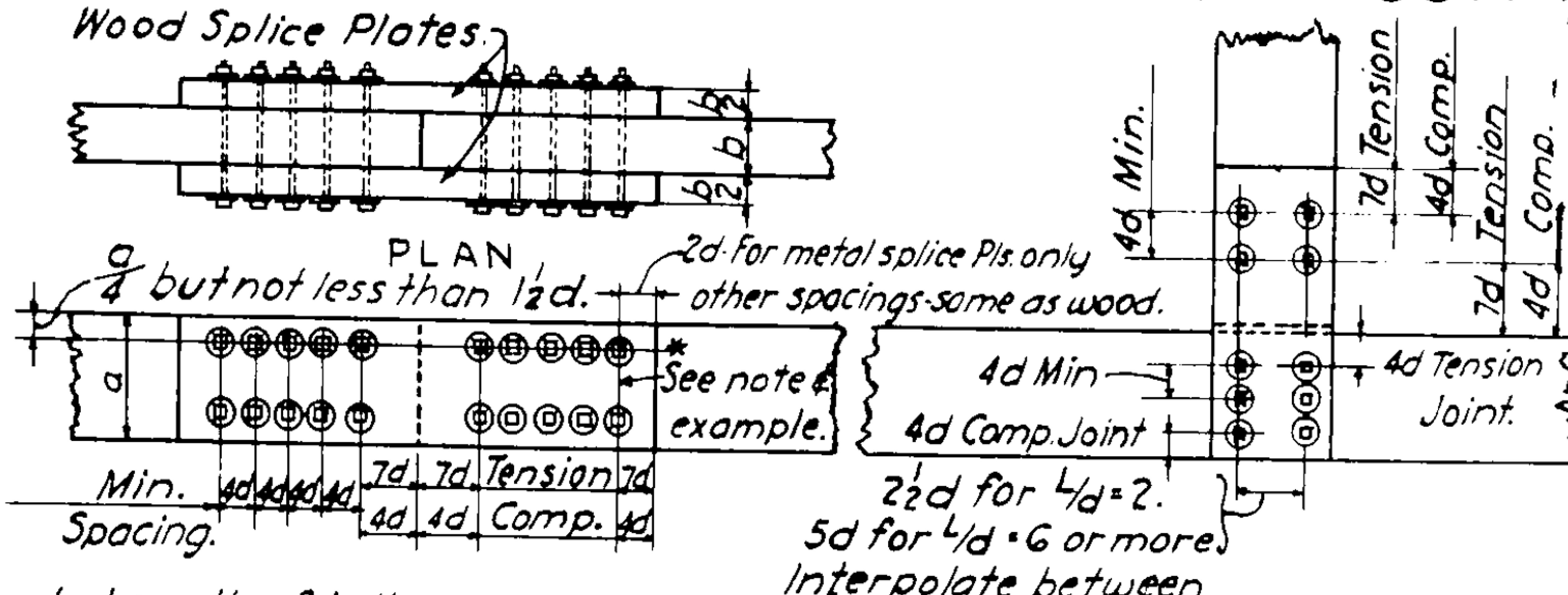
TABLE C - WIRE NAIL DATA.

PENNYWEIGHT.	4	6	8	10	12	16	20	30	40	50	60
LENGTH.	1 1/2"	2"	2 1/2"	3"	3 1/4"	3 1/2"	4"	4 1/2"	5"	5 1/2"	6"
DIAMETER (INCHES).	0.098	0.113	0.131	0.148	0.148	0.162	0.192	0.207	0.225	0.244	0.263

Adapted from Wood Handbook of Forest Products Laboratory - United States Dept. of Agriculture, with 20% increase in stresses as allowed by War Production Board directive No. 29.

STRUCTURAL - WOOD

BASIC DATA FOR BOLTED WOOD CONNECTIONS.



L = Length of bolt in bearing in inches (thickness of main member, L = b).
d = Diameter of bolt in inches.

ELEVATIONS.

*NOTE: The net tension area of the critical section shall be: ≥ 80% of bolt bearing area for softwoods, and 100% of bolt bearing area for hardwoods.

Example:

Given: Main member Douglas fir (softwood); 6x10 (area = 52.25□"); 10-¾" bolts.
Required: Net tension area at critical section
Net area = 52.25 - 2(.75 x 5.5) = 44□"
Check that this area is ≥ 80% of bearing area under all bolts = 0.8 x 10 (.75 x 5.5) = 33□"

TABLE A - UNIT BEARING STRESSES FOR CALCULATING SAFE LOADS IN LB/SQ.IN. FOR BOLTED JOINTS IN DOUBLE SHEAR.

SPECIES	L/D	Parallel To Grain: P — Wood Splice Plates	Parallel To Grain: P — Metal Splice Plates	Perpendicular To Grain: Q — Diameter Of Bolt 5/8"	3/4"	7/8"	1"	1 1/4"	1 1/2"
SOFTWOODS (Conifers): Cedar, northern and southern; fir, balsam and commercial white; hemlock, eastern; pine, lodgepole, ponderosa, sugar, northern white, and western white; spruce, Engelmann, red, Sitka, and white.	2	770	960	274	253	240	228	214	205
	4	770	960	274	253	240	228	214	205
	6	660	825	274	253	240	228	214	205
	8	492	614	274	253	240	228	214	205
	10	394	492	233	215	204	194	182	175
	12	329	412	188	173	165	157	147	141
Cedar, Alaska, incense, Port Orford, and western red; Douglas Fir (Rocky Mountain region), hemlock, western; pine, Norway.	2	960	1200	365	338	320	305	285	274
	4	935	1170	365	338	320	305	285	274
	6	728	910	365	338	320	305	285	274
	8	547	684	351	325	307	293	274	263
	10	437	546	278	258	243	232	218	209
	12	365	456	223	206	195	186	174	167
Cedar, eastern red; cypress, southern; Douglas fir (coast region); larch, western; pine, southern yellow; redwood; tamarack.	2	1248	1560	502	465	440	419	393	376
	4	1150	1440	502	465	440	419	393	376
	6	836	1045	502	465	440	419	393	376
	8	629	787	442	409	387	369	346	331
	10	505	631	337	312	295	281	264	253
	1.2	423	528	261	242	229	218	204	195
HARDWOODS (broad leaved species): Ash, commercial white and Oregon; beech; birch, sweet and yellow; cherry, black; elm, rock; hickory, true and pecan; honey locust; locust, black; maple (hard), black and sugar; oak, commercial red and white; walnut, black.	2	1440	1800	730	675	640	610	572	547
	4	1332	1670	730	675	640	610	572	547
	6	972	1215	703	650	615	587	550	527
	8	730	913	548	505	480	457	428	410
	10	581	727	405	374	354	338	316	303
	12	486	607	310	286	272	259	243	232

ALLOWABLE BOLT VALUE "N" FOR BOLT LOAD AT ANY ANGLE TO GRAIN IN POUNDS.

HANKINSON FORMULA: $N = \frac{PQA}{P\,\mathrm{Sine}^2\theta + Q\,\mathrm{Cosine}^2\theta}$. $N = PA$ for $\theta = 0°$; $N = QA$ for $\theta = 90°$

For "P" and "Q" see Table A; A = Projected Area (Dia. x length in main member).
θ = Angle between direction of load and direction of grain.

TABLE B.

Function \ Angle	0°	20°	30°	45°	60°	90°
$\mathrm{Sine}^2\theta$	0	0.12	0.25	0.50	0.75	1.0
$\mathrm{Cosine}^2\theta$	1.0	0.88	0.75	0.50	0.25	0

EXAMPLE Nº 1.

Given: ⅞" Bolts; 2" Wood Splice Plates; 4" Main Member; Load parallel to grain using Norway Pine - Group Nº 2 Softwoods.
Required: To find bolt value "N" using formula.
From Table "A" - Interpolate L/d = 4.57, value of P = 876
$N = 876 \times 4 \times \frac{7}{8} = 3060$ lbs.

EXAMPLE Nº 2.

Given: Same conditions as Example Nº 1, except $\theta = 30°$
Required: To Find "N" using Hankinson Formula.
From Table "A" - P = 876 lbs.; Q = 320 lbs.; Table "B" $\mathrm{Sin}^2\theta$ = .25; $\mathrm{Cos}^2\theta$ = .75 for $\theta = 30°$
$N = \frac{876 \times 320 \times 4 \times \frac{7}{8}}{876 \times .25 + 320 \times .75} = 2140$ lbs.

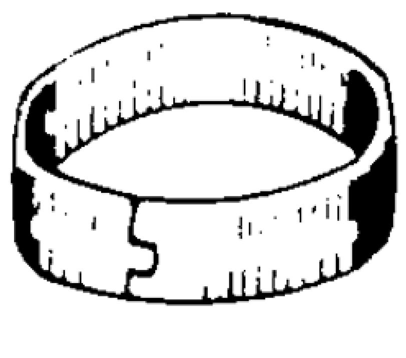
NOTE: Values in Table A are based on seasoned material in dry locations. For green material which may season after installation use 1/3 of the tabulated bolt loads. For material occasionally wet use 3/4 of the tabulated bolt loads. For material usually wet use 2/3 of the tabulated bolt loads.

Adapted from Wood Handbook of Forest Products Laboratory - United States Dep't of Agriculture with 20% increase in stresses as allowed by War Production Board directive Nº 29.

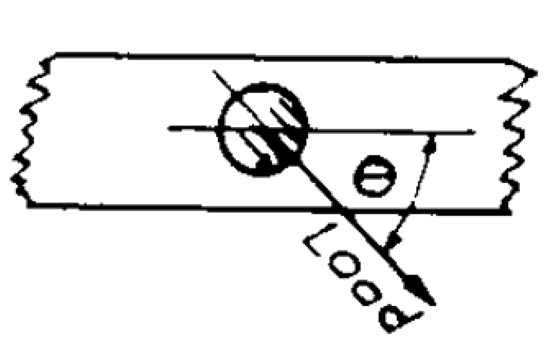
STRUCTURAL - WOOD

SPLIT RING TIMBER CONNECTORS.

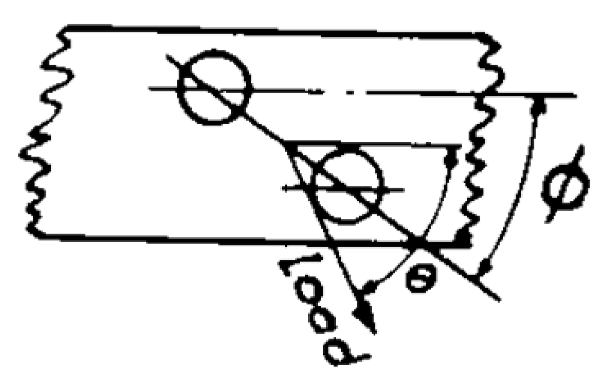
See Pg. 2-17



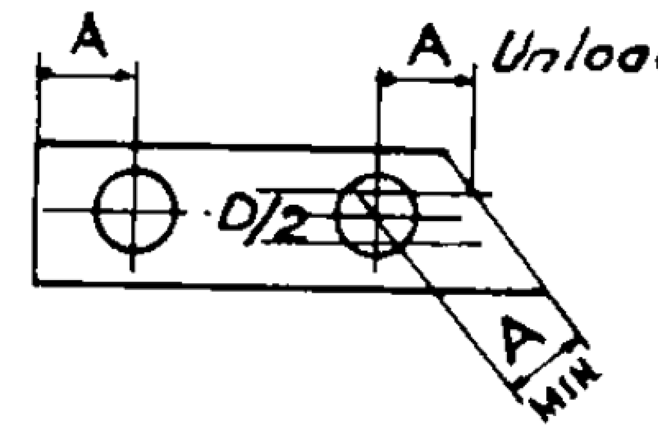
SPLIT RING



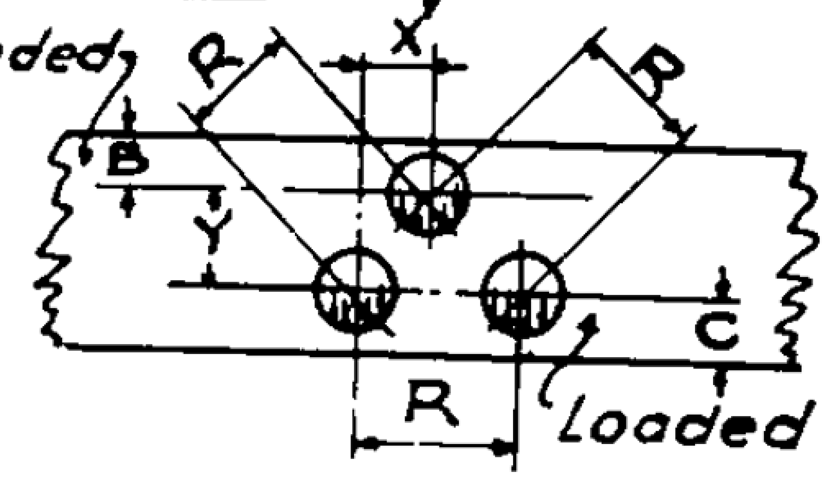
ANGLE OF LOAD TO GRAIN θ
FIGURE 1



ANGLE OF CONNECTOR AXIS TO GRAIN φ
FIGURE 2



END DISTANCE "A"
FIGURE 3



EDGE DISTANCES "B & C" AND SPACING R
FIGURE 4

TABLE A - CONNECTOR LOAD GROUPING OF SPECIES WHEN STRUCTURALLY GRADED		% OF VALUES TABLE "B"
Group "A"	Ash (White) Beech, Birch, Douglas Fir (Dense)*, Elm (Rock), Hickory, Pecan, Maple (Hard), Oak (Red & White), Pine, Southern (Dense)*	116 %
Group "B"	Douglas Fir (Coast Region), Elm (Soft), Larch (Western), Pine (Southern), Gum (Black or Red).	100 %
Group "C"	Cypress (Southern & Tidewater Red), Hemlock (West Coast), Pine (Norway), Redwood, Poplar (Yellow), Spruce (Eastern), Spruce (Sitka).	84 %
Group "D"	Cedar (Western Red), Fir (Commercial White), Hemlock (Eastern), Pine (Ponderosa), Pine (Sugar), Pine (Eastern White), Pine (Western White), Spruce (Engelmann).	72 %

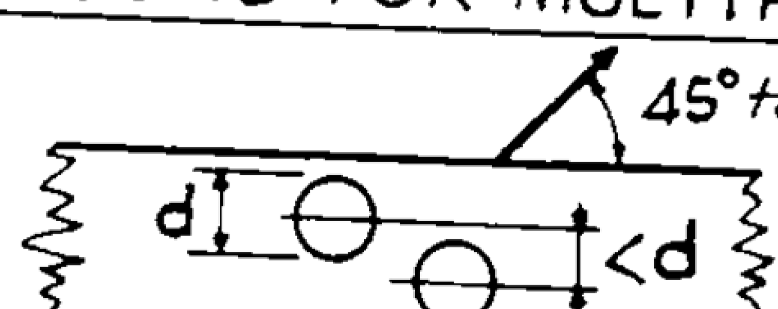
* Dense Grades are noted on Pages 1-03 & 1-04 with subnotation 7.

TABLE B - STANDARD DESIGN LOADS FOR ONE SPLIT RING & BOLT IN SINGLE SHEAR GROUP "B".

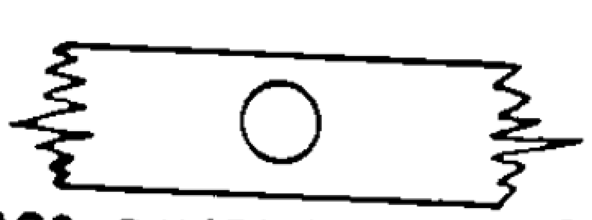
SPLIT RING CONNECTOR.			NET LUMBER THICKNESS FOR CONNECTOR USED.		ALLOWABLE LOADS IN POUNDS PER CONNECTOR AND BOLT AT ANGLE OF LOAD TO GRAIN θ.						
INSIDE DIAM.	WASHER	BOLT DIAM.	ONE FACE	TWO FACES	0°	15°	30°	45°	60°	75°	90°
2 1/2"	2 1/8" Φ 3/32" or 2×2×1/8	1/2" Φ	1" Min.	1 5/8" Min.	1653	1607	1493	1370	1267	1193	1167
			1 5/8 & Thicker	2" & Thicker	1983	1933	1800	1647	1520	1433	1403
4"	3" Φ × 5/32" or 3×3×3/16"	3/4" Φ	1" Min.		2533	2473	2307	2080	1933	1800	1777
				1 5/8" Min.	2683	2607	2413	2200	2020	1907	1867
				2" "	3087	3000	2787	2533	2333	2193	2133
				2 5/8" "	3757	3667	3400	3080	2840	2673	2617
			1 5/8" & Thicker	3" & Thicker	3823	3720	3460	3140	2893	2733	2663

NOTES: 1. Table B is for Unseasoned lumber. Increase values 50% for thoroughly seasoned lumber. Connectors act as keys, not as pins, therefore their bolts must remain tight.
2. For Angles to Grain θ other than shown, Values may be interpolated.
3. Lumber thicknesses less than shown are not recommended.
4. Minimum width of lumber is 3 5/8" for 2 1/2" Ring and 5 1/2" for 4" Ring for θ = 0.
5. For wind load, Values in Table "B" may be increased 50%.

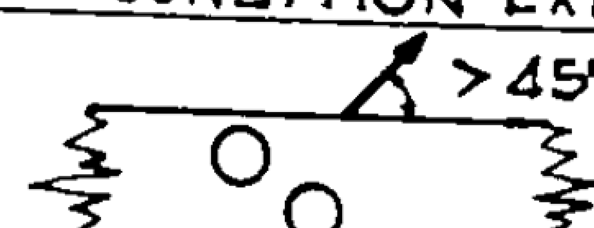
LOAD REDUCTIONS FOR MULTIPLE CONNECTORS.



LIMITATIONS APPLY ONLY WHEN ABOVE CONDITION EXISTS.



2 RINGS SINGLE SHEAR (1 EACH FACE).
No Reduction necessary.



4 RINGS S.S. (2 EACH FACE).
Reduce load as per table.

Also check for Horizontal Shear.

TABLE C - MAX. RECOMMENDED VALUE FOR GROUP OF CONNECTORS ACTING AT 45° to 90° TO THE GRAIN. VALUE FOR 4 CONNECTORS BASED ON % OF ALLOWABLE LOAD FOR 1 CONNECTOR.

SIZE OF SPLIT RING	THICKNESS OF LOADED MEMBER IN INCHES			
	1 5/8	2	2 5/8	3 or thicker
2 1/2"	300	300	300	300
4"	230	248	269	300

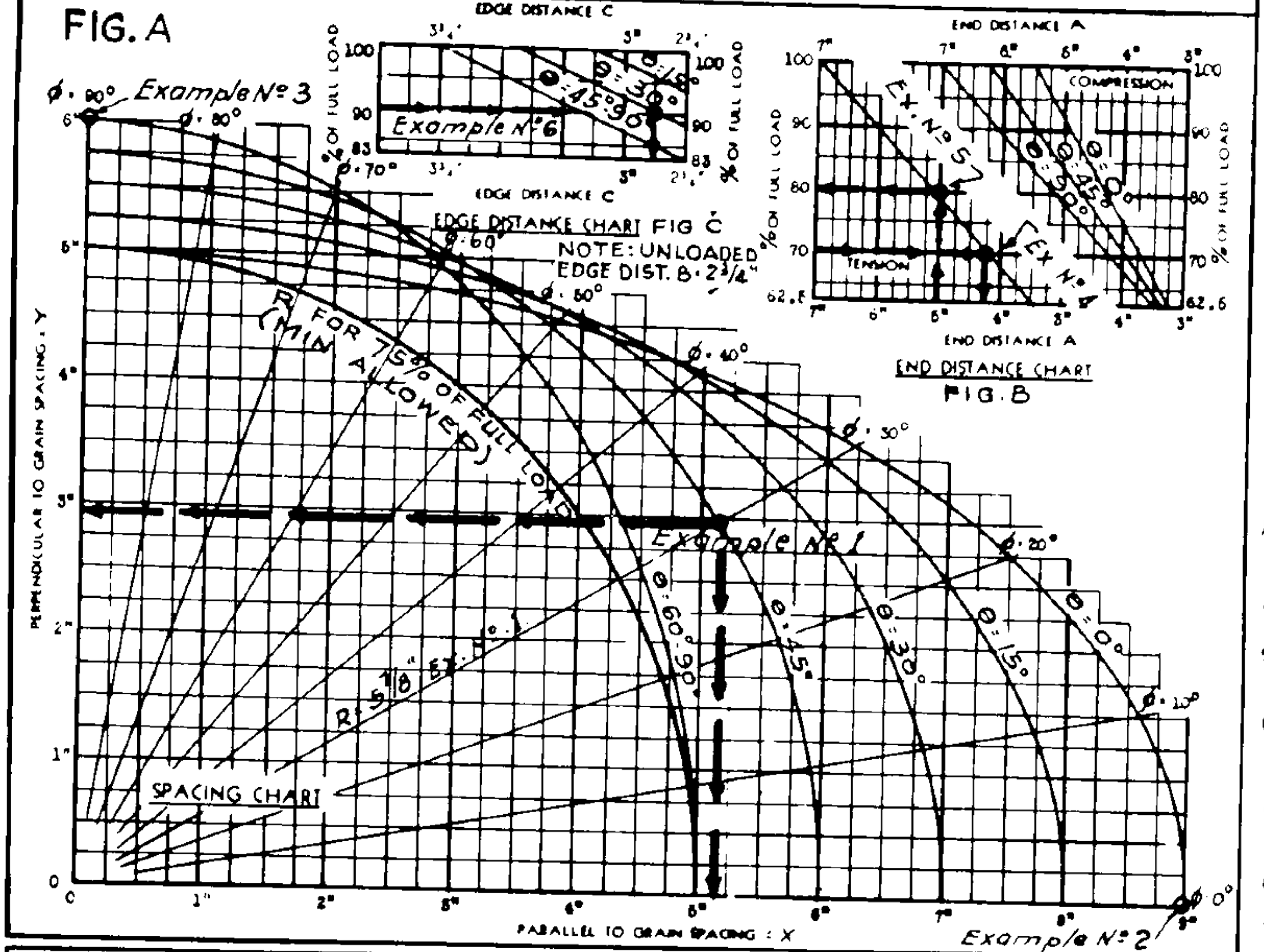
For Each additional Connector add 33% of allow. load for 1 Connector.

Adapted from Teco Design Manual No. 1, Timber Engineering Co. and Directive No 29 - War Production Board.

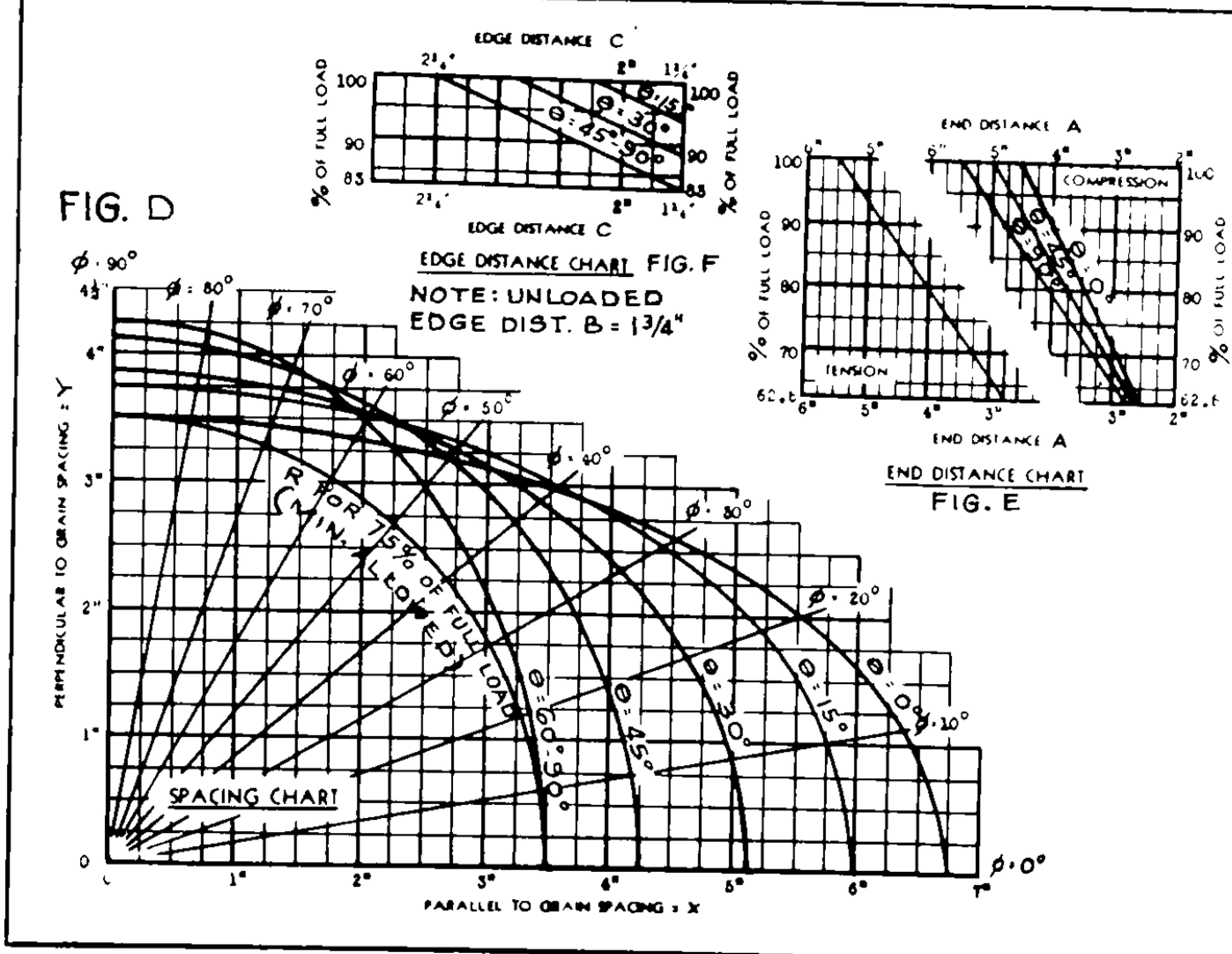
STRUCTURAL — WOOD

SPLIT RING TIMBER CONNECTORS.

CHARTS FOR 4" SPLIT RING.



CHARTS FOR 2½" SPLIT RING.



EXPLANATION OF CHARTS USING 4" CONNECTORS. FOR DETAILS, SEE FIGURES 1, 2, 3, & 4, Pg. 2-16.

SPACING CHART, FIG. A.

Example Nº 1. Given: θ = 45° & φ = 30°
Required: R
Solution: Enter Chart at intersection of θ = 45° and φ = 30°, scale R = 5 7/8" or read components Y = 2 15/16"; X = 5 1/8" for Full Load.
If in Example Nº 1, R = 5", use 75% of Full Load which is Min. Spacing for 4" Rings, See 75% Curve. For Values of R between 5" & 5 7/8" interpolate between 75% & 100%.

Example Nº 2. Given: θ = 0°, φ = 0°
Required: R. Solution: Enter Chart for θ = 0° & φ = 0°
Read R or X = 9, Y = 0

Example Nº 3. Given: θ = 90°, φ = 90°.
Required: R. Solution: Enter Chart for θ = 90°, φ = 90°
Read R = 6, X = 0, Y = 6.

END DISTANCE CHART, FIG. B.

Example Nº 4. Given: Tension end with 70% of Full Load.
Required: A.
Solution: Enter Chart for 70%, carry over to line and Read A = 4 1/4".

Example Nº 5. Given: Tension end with A = 5".
Required: % of Full Load.
Solution: Enter Chart for A = 5", carry up to line & read % = 80%. For Compression ends use same procedure using line for proper θ.

EDGE DISTANCE CHART, FIG. C.

Example Nº 6. Given: Loaded edge with θ = 30° & 90% of Full Load.
Required: C.
Solution: Enter Chart for 90%, carry over to θ = 30° & read 2 7/8". For Unloaded edge distances see charts.

Use Charts for 2½" Connector in Similar manner.

NOTE: When values of Connectors are reduced for decreases in spacing, end distances or edge distances, reductions are not cumulative.

Adapted from Teco Design Manual Nº 1, Timber Engineering Co. and Directive Nº 29 - War Production Board.

STRUCTURAL — PLYWOOD

TABLE A – DOUGLAS FIR PLYWOOD WORKING STRESSES DAMP OR WET LOCATION – TO BE APPLIED TO STRESS RESISTING PLIES ONLY.† SEE Pg. 2-21.

STRESS \ GRADE	Clear 100% G-2-S (These two exterior grades available only on Special Mill Order)	95% G-1-S	87½% So-2-S	80% Plywall or So-1-S	75% Sheathing
Extreme Fibre in Bending	2000	1900	1750	1600	1500
Compression perpendicular to grain	325	325	325	325	325
Compression parallel to grain—3-ply only; for 5-ply and thicker Use next lower grade except no change for 75% grade.	1466	1390	1285	1170	1100
Maximum horizontal shear	120	114	105	96	90
Modulus of Elasticity	1,600,000	1,600,000	1,600,000	1,600,000	1,600,000

NOTES: For basic working stresses of lumber other than Douglas Fir, See Pgs. 1-03 & 1-04. Where moisture content of plywood under load does not exceed 16%, above working stresses may be increased 25%.

G-2-S = good 2 sides ; G-1-S = good 1 side ; So-2-S = Sound 2 sides ; So-1-S = Sound 1 side.

TABLE B – MOMENTS OF INERTIA, SECTION MODULI and VENEER AREAS for SELECTED PLYWOOD CONSTRUCTIONS.†

(12" WIDTHS)

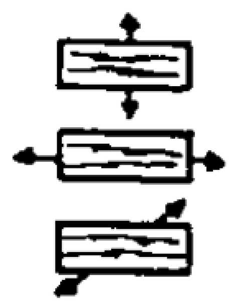
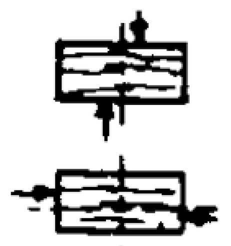
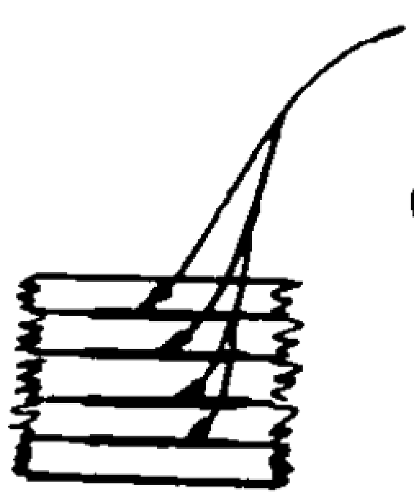
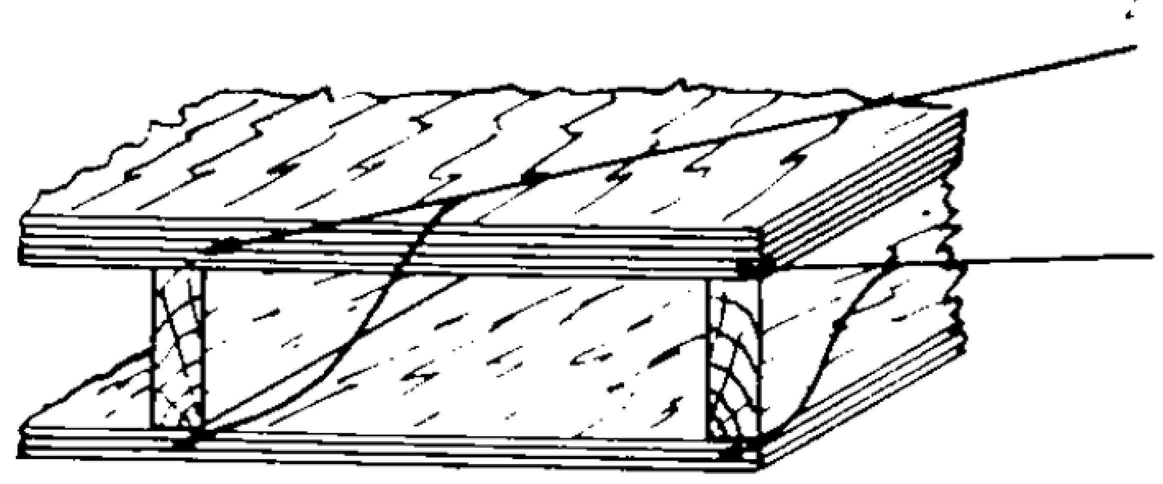
Plywood Thickness (net)	No. of Plies	Veneer Thickness (Nominal) in Inches: Faces*	Centers	Crossband	Parallel³ Plies Only: Area (Sq. Ins.)	Moment of Inertia I (Inches⁴)	Section Modulus S (Inches³)	Perpendicular³ Plies Only: Area (Square Inches)	Moment of Inertia I (Inches⁴)	Section Modulus S (Inches³)	Weight, lbs. per 1000 sq. ft. (Approx.) (As shipped from Mill)
1/8"—R(1)	3	1/24	1/24		1.00	.0019	.030	0.50	.0001	.0034	490
1/8"—S(2)	3	1/16	1/16		0.75	.0017	.027	0.75	.0002	.0077	490
3/16"—R	3	1/16	1/16		1.50	.0064	.068	0.75	.0002	.0077	640
3/16"—S	3	1/12	1/12		1.25	.0060	.064	1.00	.0006	.0139	640
1/4"—R	3	1/12	1/12		2.00	.0150	.120	1.00	.0006	.0139	790
1/4"—S	3	1/9	1/9		1.67	.0143	.114	1.33	.0014	.0247	790
5/16"—R	3	1/10+	1/10+		2.50	.0294	.188	1.25	.0011	.0215	950
5/16"—S	3	1/8	1/8		2.25	.0286	.183	1.50	.0020	.0312	950
3/8"—R	3	1/8	1/8		3.00	.0509	.271	1.50	.0020	.0312	1125
3/8"—S	3	1/8	3/16		2.25	.0461	.246	2.25	.0066	.0704	1125
3/8"—S	5	1/10	1/12	2@1/12	2.50	.0377	.201	2.00	.0150	.120	1125
7/16"—R	3	1/8	3/16		3.00	.0772	.353	2.25	.0066	.0704	1300
7/16"—R	5	1/10	1/12	2@1/12	3.25	.0688	.314	2.00	.0150	.120	1125
7/16"—S	5	1/10	1/10	2@1/10	2.85	.0575	.263	2.40	.0260	.1735	1300
1/2"—R	5	1/10	1/10	2@1/10	3.60	.0990	.396	2.40	.0260	.1735	1525
1/2"—S	5	1/8	1/8	2@1/10	3.60	.0926	.370	2.40	.0324	.1995	1525
9/16"—R	5	1/8	1/8	2@1/10	4.35	.1457	.517	2.40	.0324	.1995	1675
9/16"—S	5	1/8	1/8	2@1/8	3.75	.1273	.452	3.00	.0507	.271	1675
5/8"—R	5	1/8	1/8	2@1/8	4.50	.1934	.619	3.00	.0507	.271	1825
5/8"—S	5	1/8	3/16	2@1/8	4.50	.1670	.534	3.00	.0771	.352	1825
11/16"—R	5	1/8	3/16	2@1/8	5.25	.2478	.720	3.00	.0771	.352	2000
11/16"—S	5	1/8	1/8	2@3/16	3.75	.202	.588	4.50	.123	.492	2000
3/4"—R	5	1/8	1/8	2@3/16	4.50	.299	.798	4.50	.123	.492	2225
3/4"—S	5	1/8	3/16	2@3/16	4.50	.251	.670	4.50	.171	.608	2225
3/4"—S	7	1/8	2@1/12	3@1/8	4.50	.286	.763	4.50	.136	.503	2225
13/16"—R	5	1/8	3/16	2@3/16	5.25	.365	.898	4.50	.171	.608	2375
13/16"—R	7	1/8	2@1/12	3@1/8	5.25	.401	.988	4.50	.136	.503	2225
13/16"—S	7	1/8	2@1/8	3@1/8	5.25	.343	.845	4.50	.193	.617	2375
7/8"—R	7	1/8	2@1/8	3@1/8	6.00	.477	1.090	4.50	.193	.617	2600
7/8"—S	7	1/8	2@5/32	3@1/8	6.00	.427	.976	4.50	.243	.707	2600
15/16"—R	7	1/8	2@5/32	3@1/8	6.75	.581	1.241	4.50	.243	.707	2800
15/16"—S	7	1/8	2@3/16	3@1/8	6.75	.525	1.120	4.50	.299	.797	2800
1" —R	7	1/8	2@3/16	3@1/8	7.50	.701	1.402	4.50	.299	.797	3000
1" —S	7	1/8	2@1/8	3@3/16	5.25	.540	1.080	6.75	.460	1.131	3000
1-1/16"—R	7	1/8	2@1/8	3@3/16	6.00	.740	1.393	6.75	.460	1.131	3175
1-1/16"—S	7	1/8	2@1/6	3@3/16	6.00	.615	1.157	6.75	.585	1.305	3175
1-1/8"—R	7	1/8	2@1/6	3@3/16	6.75	.839	1.490	6.75	.585	1.305	3350
1-1/8"—S	7	1/8	2@3/16	3@3/16	6.75	.771	1.371	6.75	.653	1.395	3350
1-3/16"—R	7	1/8	2@3/16	3@3/16	7.50	1.022	1.725	6.75	.653	1.395	3525
1-3/16"—S	7	1/8	2@7/32	3@3/16	7.50	.912	1.538	6.75	.763	1.526	3525

¹Rough; ²Sanded; ³Refers to direction of face grain; *For sanded panels, thickness is before sanding.

Adapted From Perkins And Countryman, "Technical Data on Plywood" Douglas Fir Plywood Assoc.

STRUCTURAL — PLYWOOD

APPLICATION OF PLYWOOD STRESSES TO DESIGN.*

PROPERTY	DIRECTION OF STRESS WITH RESPECT TO DIRECTION OF FACE GRAIN	PORTION OF CROSS-SECTIONAL AREA TO BE CONSIDERED	UNIT STRESS TO BE USED
 TENSION	Parallel or Perpendicular	Parallel plies[2] only	Unit stress for extreme fiber in bending
	± 45°	Full cross-sectional area.	One-fourth unit stress for extreme fiber in bending
COMPRESSION	Parallel or Perpendicular	Parallel plies[2] only	Unit stress in compression parallel to grain
	± 45°	Full cross-sectional area.	One-third unit stress in compression parallel to grain.
 SHEAR	Parallel or Perpendicular	Full cross-sectional area.	Double unit stress for horizontal shear.
	± 45	Full cross-sectional area	Four times unit stress for horizontal shear.
 SHEAR IN PLANE OF PLIES (ROLLING SHEAR)	Parallel, Perpendicular, or ± 45°	Full shear area 	1 Conditions without stress concentration. A. Joints between plies in plywood panels acting as a beam—one-half unit stress for horizontal shear 2 Conditions with stress concentration. A. Symmetrical concentration. Joints in panels with stressed plywood covers, for interior joists with end headers, or without end headers if ratio of joist depth to joist width does not exceed 2—one-half unit stress for horizontal shear. B Unsymmetrical concentration. Joints in I and box beams with plywood webs; and joints in panels with stressed plywood covers, for exterior joists with end headers, or without end headers if ratio of joist depth to joist width does not exceed 2—one-fourth unit stress for horizontal shear.
LOAD IN BENDING	Parallel or Perpendicular	Bending moment $M = KSI/c$ where S = unit stress for extreme fiber in bending; I = moment of inertia computed on basis of parallel plies only; c = distance from neutral axis to outer fiber of outermost ply having its grain in the direction of the span; $K = 1.50$ for three-ply plywood having the grain of the outer plies perpendicular to the span; $K = 0.85$ for all other plywood.	Unit stress for extreme fiber in bending
DEFLECTION IN BENDING	Parallel or Perpendicular	Deflection may be calculated by the usual formulas, taking as the moment of inertia that of the parallel plies plus one-twentieth that of the perpendicular plies. (When face plies are parallel, the calculation may be simplified, with but little error, by taking the moment of inertia as that of the parallel plies only.)	Unit value for modulus of elasticity
DEFORMATION IN TENSION OR COMPRESSION	Parallel or Perpendicular	Parallel plies[2] only.	Unit value for modulus of elasticity
BEARING AT RIGHT ANGLES TO PLANE OF PLYWOOD		Loaded area.	Unit stress in compression perpendicular to grain.

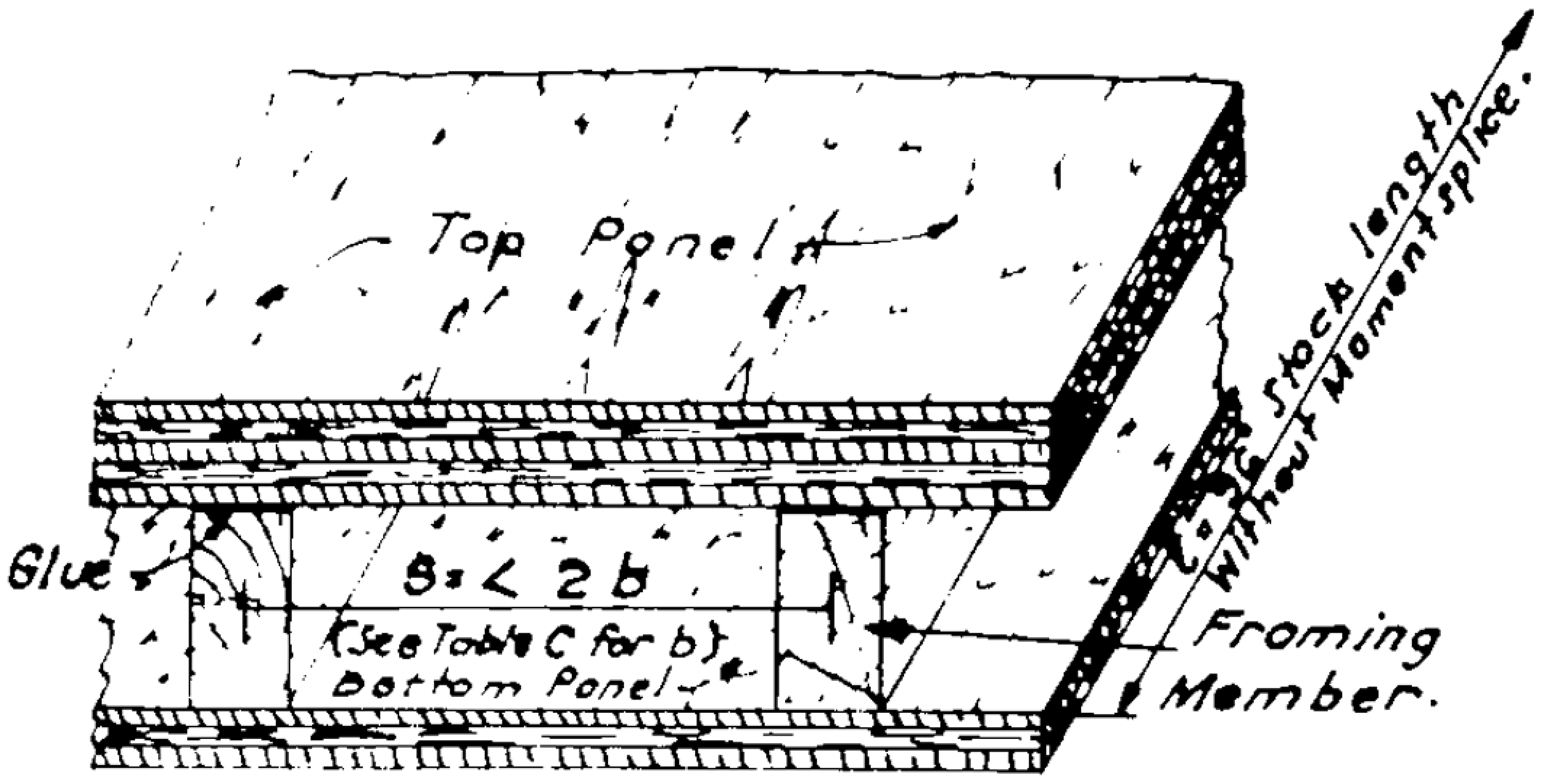
[1]The suggested simplified methods of calculation apply reasonably well with usual plywood types under ordinary conditions of service. It is recognized, however, that they are not entirely valid for all types of plywood and plywood constructions, or for all spans and span-depth ratios

[2]By "parallel plies" is meant those plies whose grain direction is parallel to the direction of principal stress.

SOURCE:
U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
MADISON, WISCONSIN
APRIL 17, 1942
(Revised)

Adapted From Perkins And Countryman, "Technical Data on Plywood" Douglas Fir Plywood Assoc.

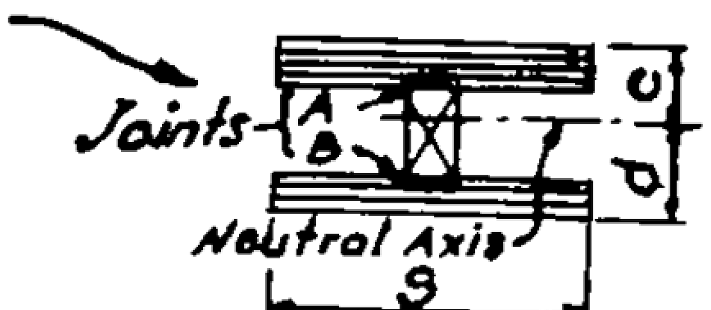
STRUCTURAL — PLYWOOD



PROBLEM is similar to Design of Box Girder with span ℓ and width S.

SOLUTION:

1. Select top & bottom panels to span "S" distance with required loading by Flexure formulas using Table B - Pg. 2-20 & "Load in bending," Pg. 2-21. Check max. horizontal shear. See "Shear in Plane of Plies," Pg. 2-21 - Par. 1-A.
2. Consider an I section. Find Neutral Axis and Moment of Inertia (I) about Neutral Axis.



3. See Fig. B and Table C below for reduction of compression stresses in top panel and tension stresses in bottom panel.
4. Resisting $M = \frac{S I}{c}$ or $\frac{S' I}{d}$; S = Compression Stresses. S' = Tension Stresses. See "Compression" & "Tension," Pg. 2-21.
5. Check rolling shear at $A = \frac{\text{Reaction} \times Q}{I \times \text{thickness of framing member}}$; Check Joint B Similarly.

I = Moment of Inertia component section.
Q = Static M above $A = t \times S \times (c - t_1)$ where t = thickness of parallel plies above Joint A and t_1 = ½ y distance shown.
Rolling shear to be less than allowable "Shear in plane of plies," Pg. 2-21 - Par. 2 A & 2 B.

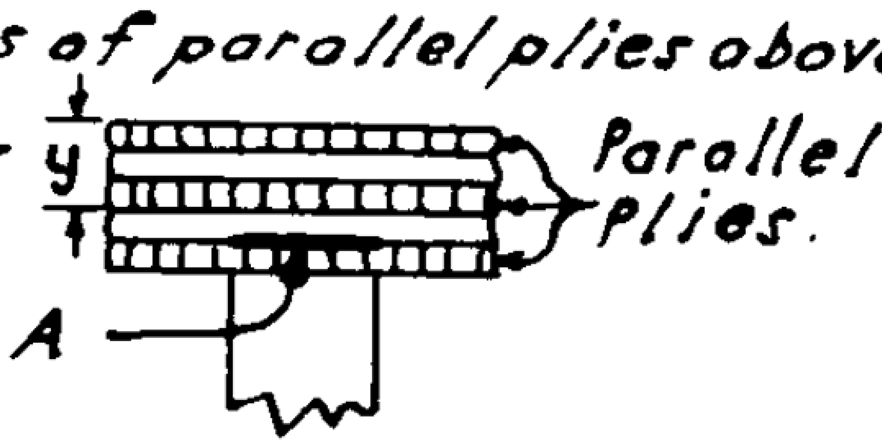


FIG. A - DESIGN OF SKIN STRESSED PANELS.

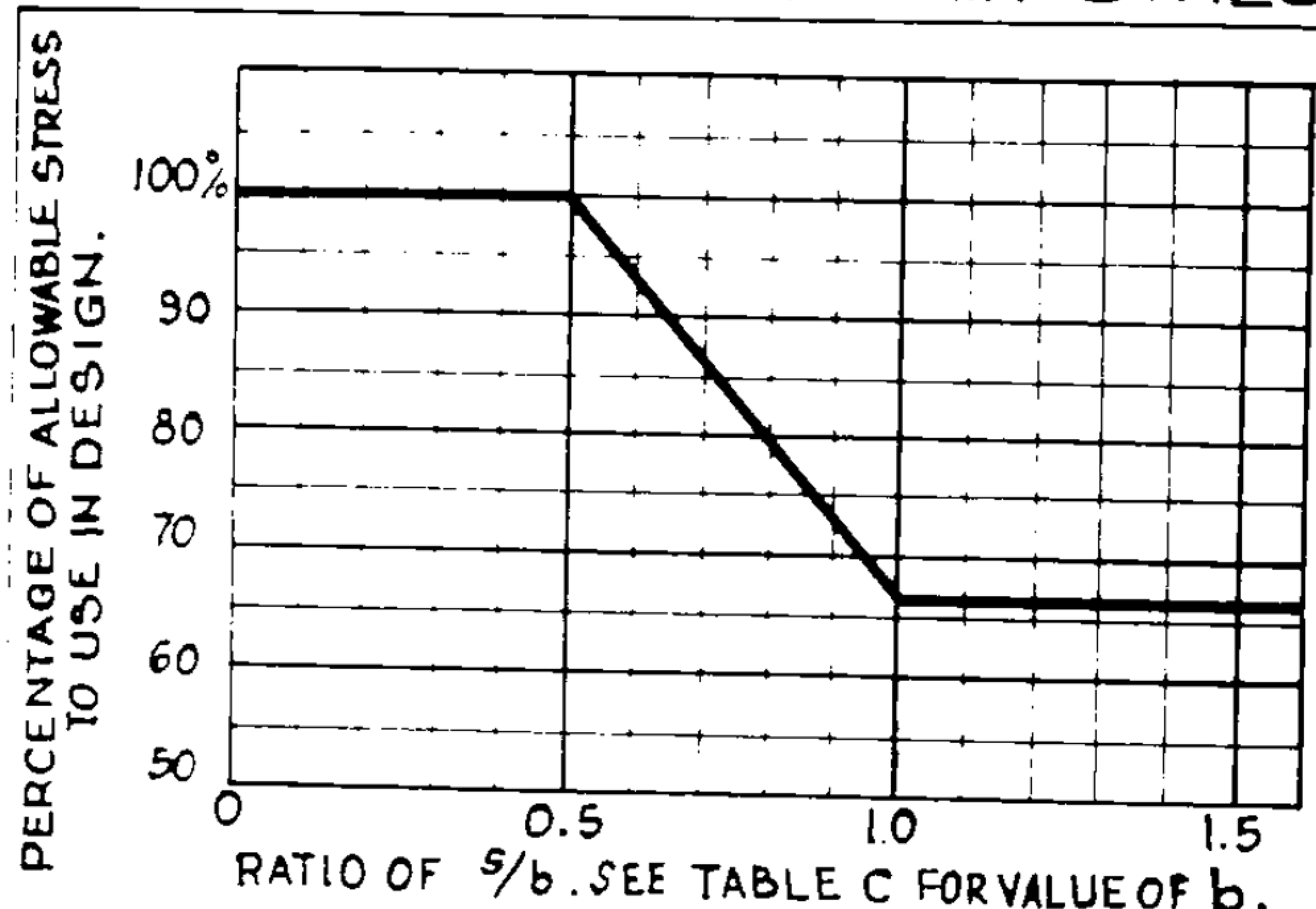


FIG. B - STRESS REDUCTION.*

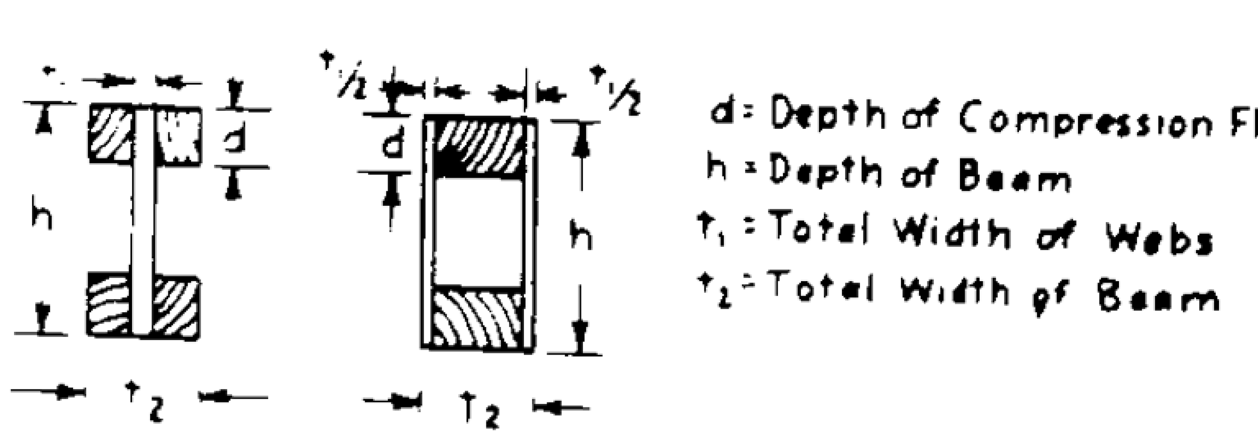
TABLE C - VALUES OF "b" FOR USE IN FIG. B.*

Plywood Thickness	Basic Spacing "b," inches — Face grain parallel to longitudinal members	Basic Spacing "b," inches — Face grain perpendicular to longitudinal members
¼" Sanded	10.35"	11.61"
5/16" Rough	11.87	16.80
⅜" Rough (3-ply)	14.25	20.13
⅜" Sanded (3-ply)	16.43	16.43
⅜" Sanded (5-ply)	18.10	20.25
½" Rough and Sanded	23.25	28.5
⅝" Rough and Sanded	29.1	35.6
¾" Sanded (5-ply and 7-ply)	38.2	38.2
⅞" Rough and Sanded	41.6	48.1
1" Rough	45.5	58.9
1" Sanded	54.5	47.9

$M = F_{P.L.} \times \frac{S I}{c}$;

Check rolling shear by "Shear in Plane of Plies, Pg. 2-21 - Par. 2B.

$F_{P.L.}$ = Form factor of Proportional Limit. Find from Chart at right.



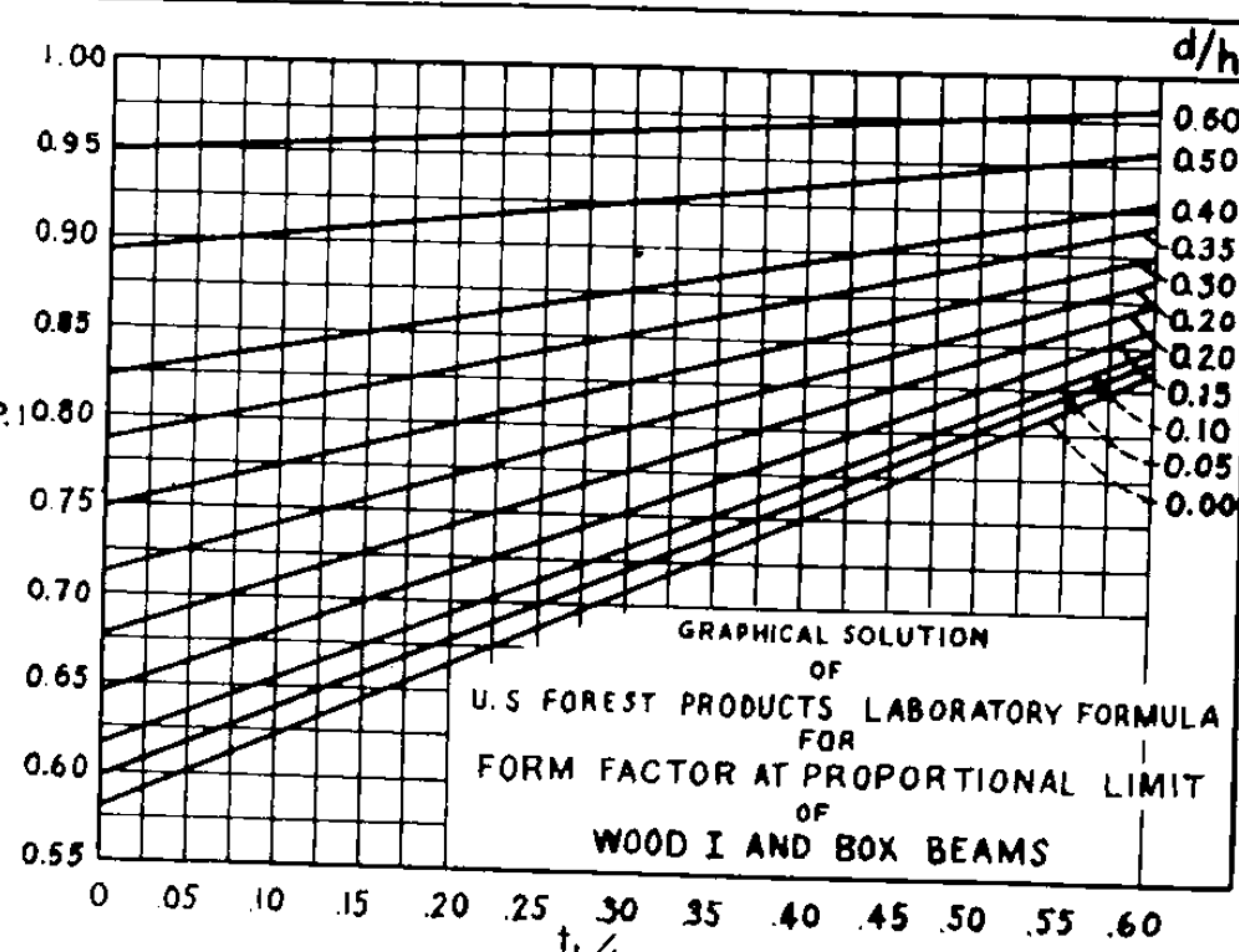


FIG. D - DESIGN OF I AND BOX BEAMS.*

*Adapted from Perkins and Countryman, "Technical Data on Plywood," Douglas Fir Plywood Assoc.

STRUCTURAL — PLYWOOD

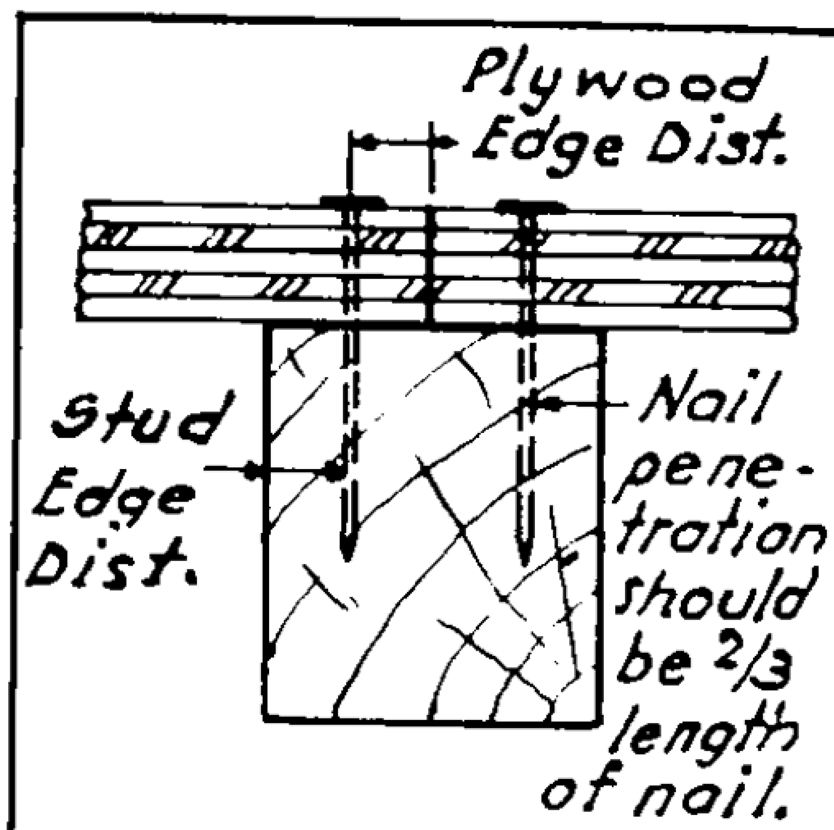


TABLE A - ULTIMATE STRENGTH IN SHEAR OF NAILS IN PLYWOOD. USE 1/6 OF VALUES FOR DESIGN.*

PLYWOOD THICKNESSES	NAIL SIZE 6d COM. LOAD	6d COM. PLYWOOD EDGE-DISTANCE	8d COM. LOAD	8d COM. PLYWOOD EDGE-DISTANCE	10d COM. LOAD	10d COM. PLYWOOD EDGE-DISTANCE	16d COM. LOAD	16d COM. PLYWOOD EDGE-DISTANCE
5/16"	335#	1/2"	420#	5/8"				
3/8"	345#	1/2"	470#	5/8"				
1/2"			470#	5/8"	500#	1/2"		
5/8"			470#	5/8"	575#	5/8"	620#	5/8"
3/4"					575#	3/4"	675#	3/4"

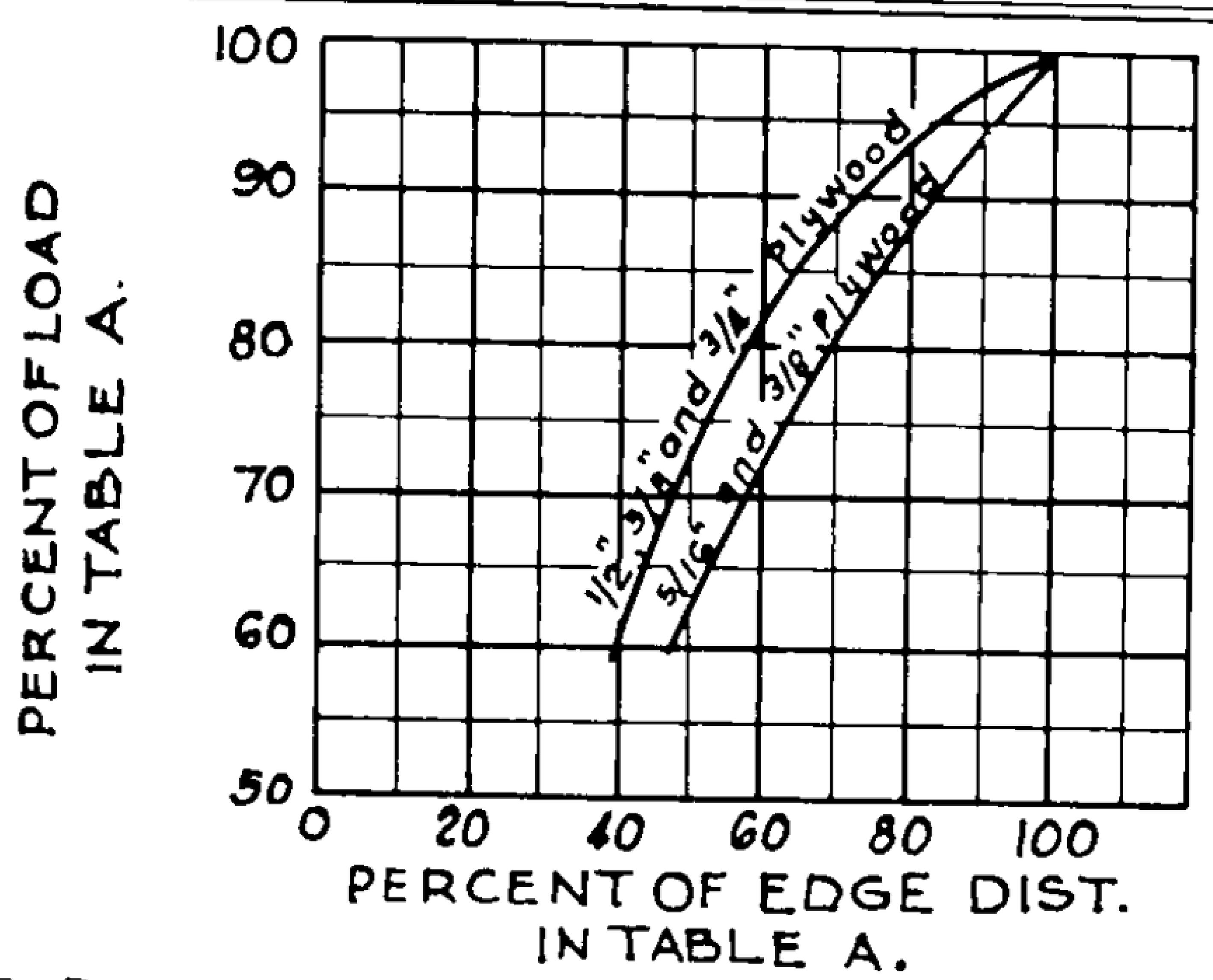


FIG. B - REDUCTION OF VALUES IN TABLE A FOR PLYWOOD EDGE DISTANCES LESS THAN THOSE SHOWN IN TABLE A.*

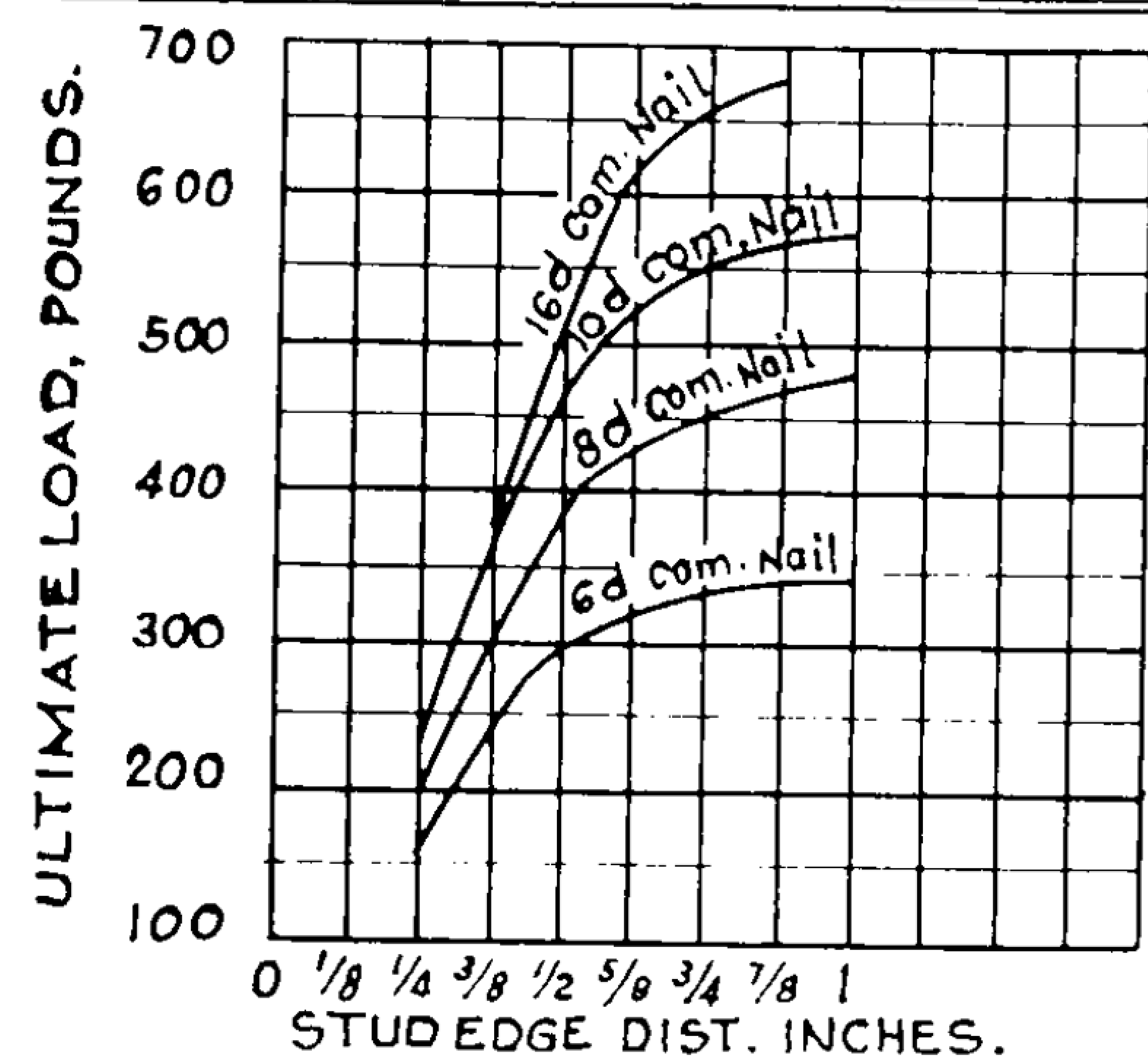


FIG. C - ULTIMATE STRENGTH IN SHEAR OF NAILS IN STUDS. USE 1/6 FOR DESIGN.*

Item	Width (Inches)	Length (Inches)	Thickness[1] (Inches) (after sanding)
Standard Panels (G2S-Ext.) (G1S-Ext.) (SO2S-Ext.) (SO1S-Ext.)	12 26 14 28 16 30 18 36 20 42 22 48 24	48 60 72 84 96	3/16 (3 ply) 3/4 (5 ply) 1/4 (3 ply) 13/16 (5 ply) 5/16 (3 ply) 7/8 (7 ply) 3/8 (3 ply) 15/16 (7 ply) 7/16 (5 ply) 1 (7 ply) 1/2 (5 ply) 1 1/16 (7 ply) 9/16 (5 ply) 1 1/8 (7 ply) 5/8 (5 ply) 1 3/16 (7 ply) 11/16 (5 ply)
Sheathing Exterior	48	96	5/16 (5 ply unsanded) 3/8 (3 ply unsanded) 1/2 (3 ply unsanded) 5/8 (3 ply unsanded)
Industrial Exterior	As Ordered	As Ordered	1/4 (3 ply unsanded) 5/16 (3 ply unsanded) 3/8 (3 ply unsanded) 7/16 (3 ply unsanded) 1/2 (5 ply unsanded) 9/16 (5 ply unsanded) 5/8 (5 ply unsanded) 11/16 (5 ply unsanded) 3/4 (5 ply unsanded) 7/8 (5 ply unsanded)
Concrete Form Panels Exterior	Same as Standard Panels	Same as Standard Panels	5/8 (3 ply sanded 2 sides) 3/4 (5 ply sanded 2 sides)

[1]Number of plies listed under thickness is minimum.

EXTERIOR TYPE

Item	Width (Inches)	Length (Inches)	Thickness (Inches) (after sanding)
Standard Panels (SO2S) (SO1S)	24 30 36 48	60 72 84 96	1/8 (3 ply) 3/16 (3 ply) 1/4 (3 ply) 3/8 (3 ply) 1/2 (5 ply) 5/8 (5 ply) 3/4 (5 ply)
Wallboard	48	60 72 84 96	1/4 (3 ply sanded 2 sides) 3/8 (3 ply sanded 2 sides) 1/2 (5 ply sanded 2 sides)
Sheathing	36 48	96	5/16 (3 ply unsanded) 3/8 (3 ply unsanded) 1/2 (3 or 5 ply unsanded) 5/8 (3 or 5 ply unsanded)
Auto-mobile and Industrial	As Ordered up to 48	As Ordered up to 96	1/4 (3 ply unsanded) 5/16 (3 ply unsanded) 3/8 (3 ply unsanded) 1/2 (5 ply unsanded) 9/16 (5 ply unsanded) 5/8 (5 ply unsanded) 11/16 (5 ply unsanded) 3/4 (5 ply unsanded) 7/8 (5 ply unsanded) 7/8 (7 ply unsanded)
Concrete Form Panels	36 48	60 72 84 96	1/4 (3 ply sanded 2 sides) 1/2 (5 ply sanded 2 sides) 9/16 (5 ply sanded 2 sides) 5/8 (5 ply sanded 2 sides) 3/4 (5 ply sanded 2 sides)

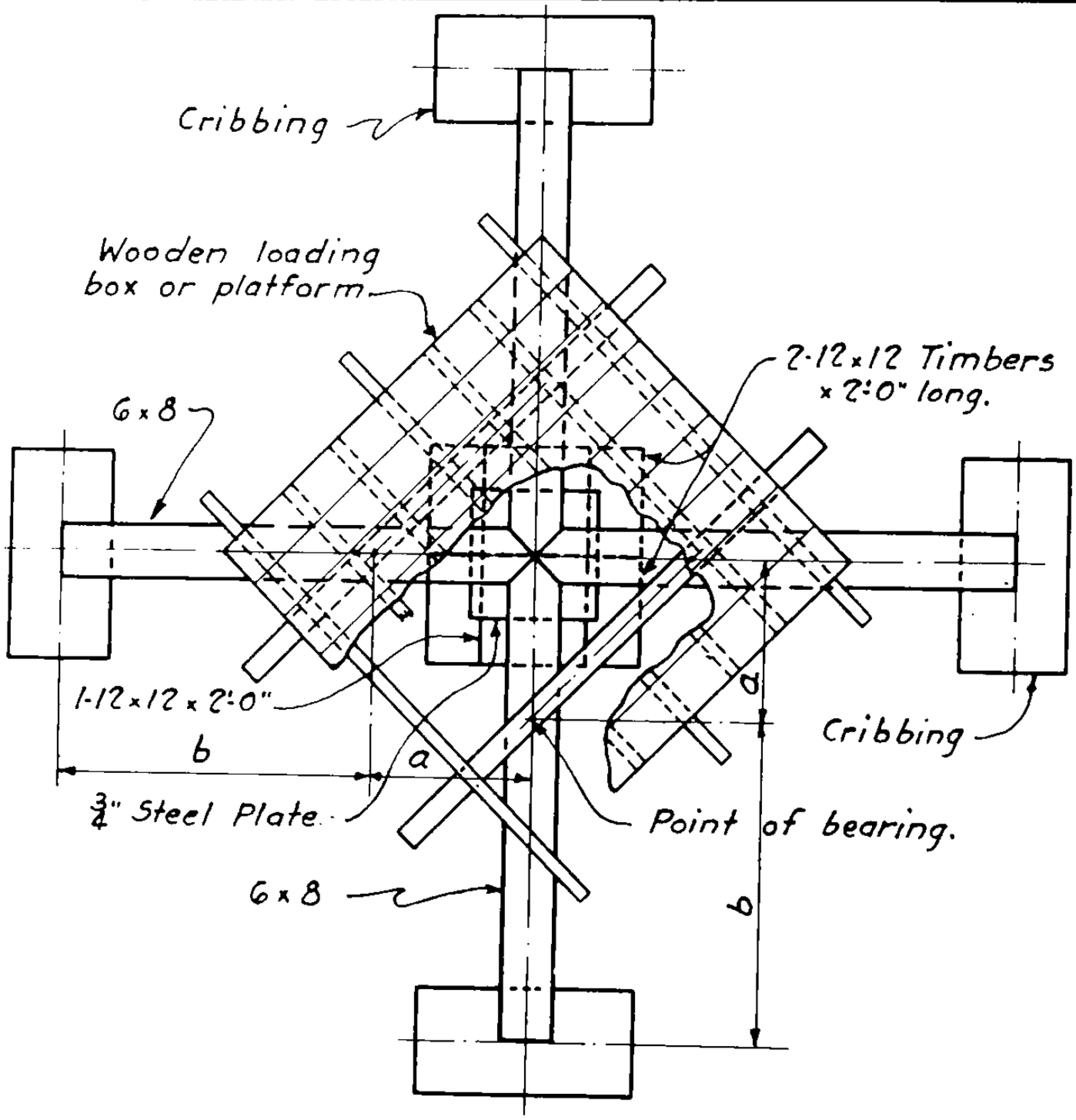
MOISTURE-RESISTANT TYPE

FIG. D - STANDARD DOUGLAS FIR PLYWOOD SIZES.*

Adapted From Perkins And Countryman, "Technical Data on Plywood" Douglas Fir Plywood Assoc.

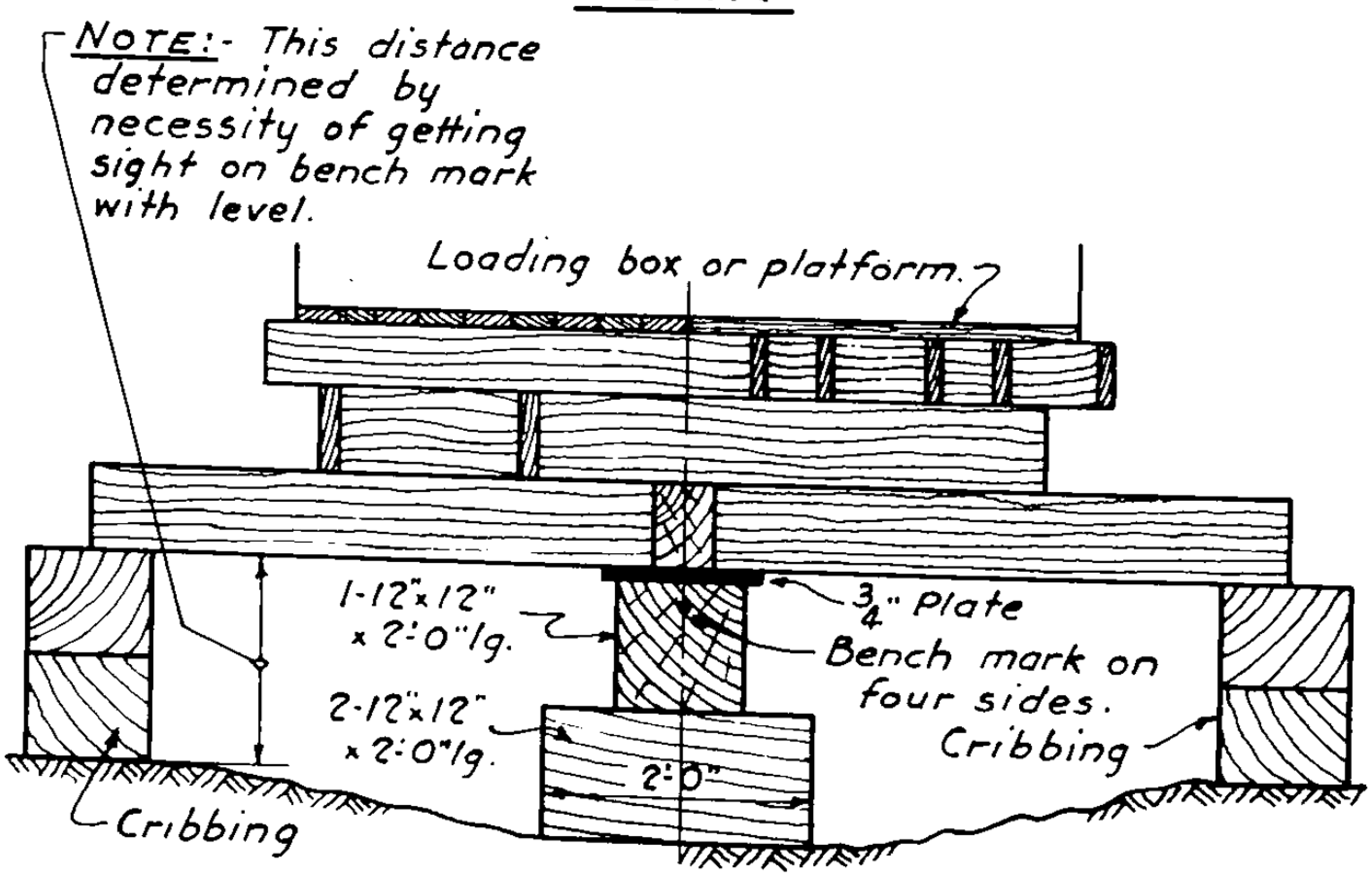
STRUCTURAL - FOUNDATIONS

METHOD OF CONDUCTING SOIL LOAD TEST* - N.Y. CITY CODE



PLAN

PROCEDURE:-
Apply sufficient load uniformly on platform to produce a center load of four times the proposed "design load per square foot." Center load equals load of platform times $\frac{b}{a+b}$.
Read settlement every 24 hours until no settlement occurs in 24 hours.
Add 50% more load and read settlement every 24 hours until no settlement occurs in 24 hours.
Settlement under proposed load should not show more than 3/4", or increment of settlement under 50% overload should not exceed 60% of settlement under proposed load.
If the above limitations are not met, repeat test with reduced load.



ELEVATION

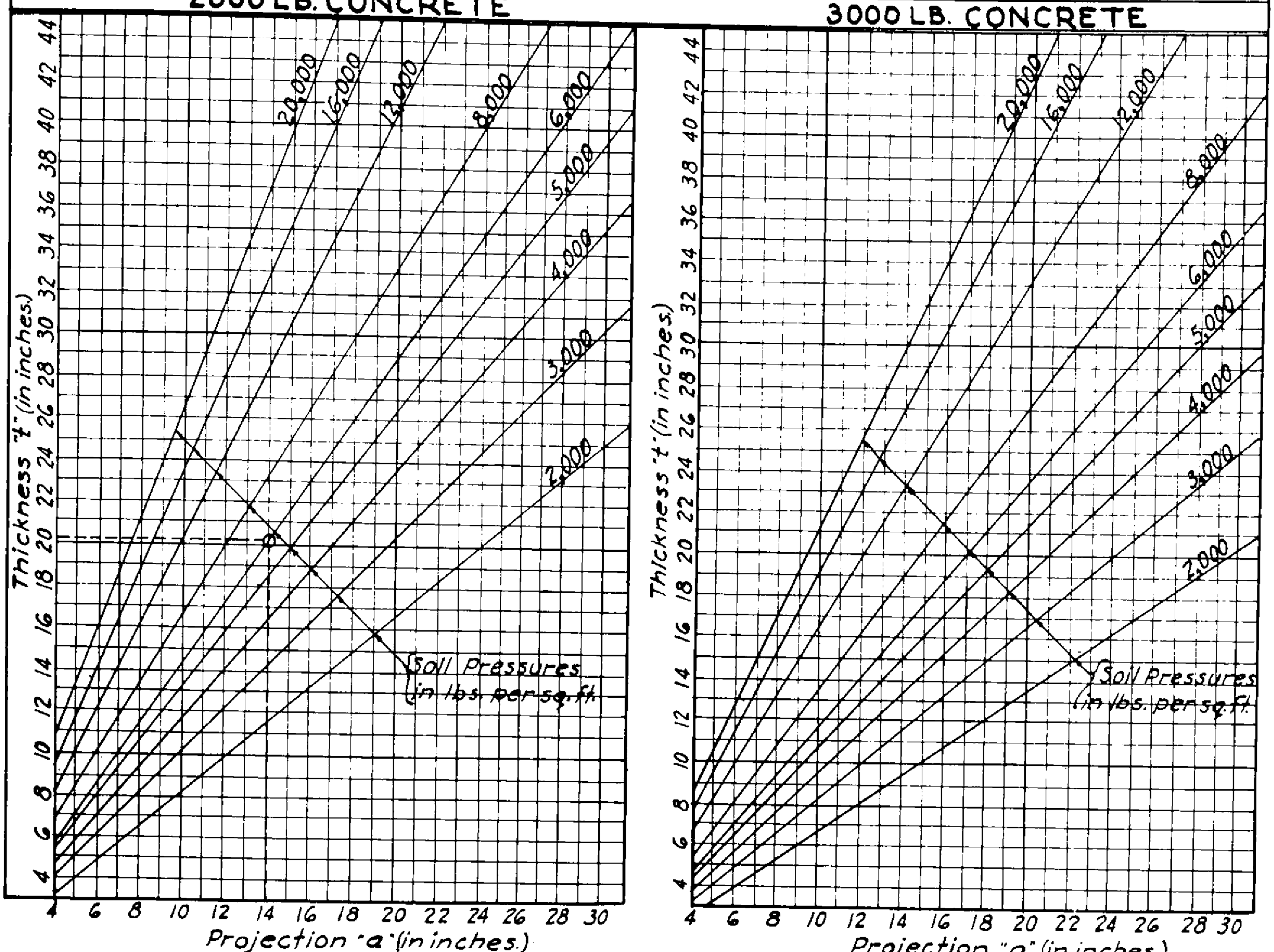
N.Y. CITY CODE
PRESUMPTIVE BEARING CAPACITY OF SOILS*

MATERIAL	CAPACITY IN TONS PER SQ. FT.
Hard Sound Rock	40
Medium Hard Rock	25
Hard Pan Overlying Rock	10
Soft Rock	8
Gravel	6
Coarse Sand	4
Fine Dry Sand	3
Hard Dry Clay	3
Sand & Clay, mixed or in layers	2
Firm Clay	2
Fine & Wet Sand (Confined)	2
Soft Clay	1

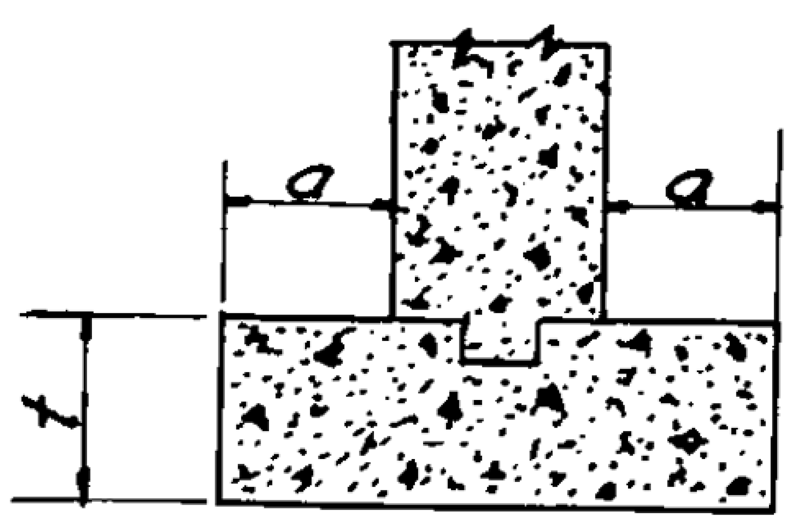
* See also Field Load Bearing Test, Pg. 4-26 and Soils, Pg. 3-20 to 3-24.

STRUCTURAL - FOUNDATIONS

PLAIN CONCRETE WALL FOOTINGS.



NOTE: The diagrams are in accordance with the requirements of the A.C.I. Code - 1941.
For Joint Committee requirements add 2 inches to the thickness "t" from the diagrams above.
For New York City Code requirements add 4 inches to the thickness "t" from the diagrams above.



Formula for plain concrete wall footings:-

$$t = a\sqrt{\frac{S}{48 f_c}}$$

In Which: t = Total depth of footing in inches.
a = Projection in inches.
S = Soil pressure in lb. per sq. ft.
$f_c = 0.03 f_c'$. e.g. $0.03 \times 3{,}000 = 90$ lb. per sq. in. for 3,000 lb. concrete.

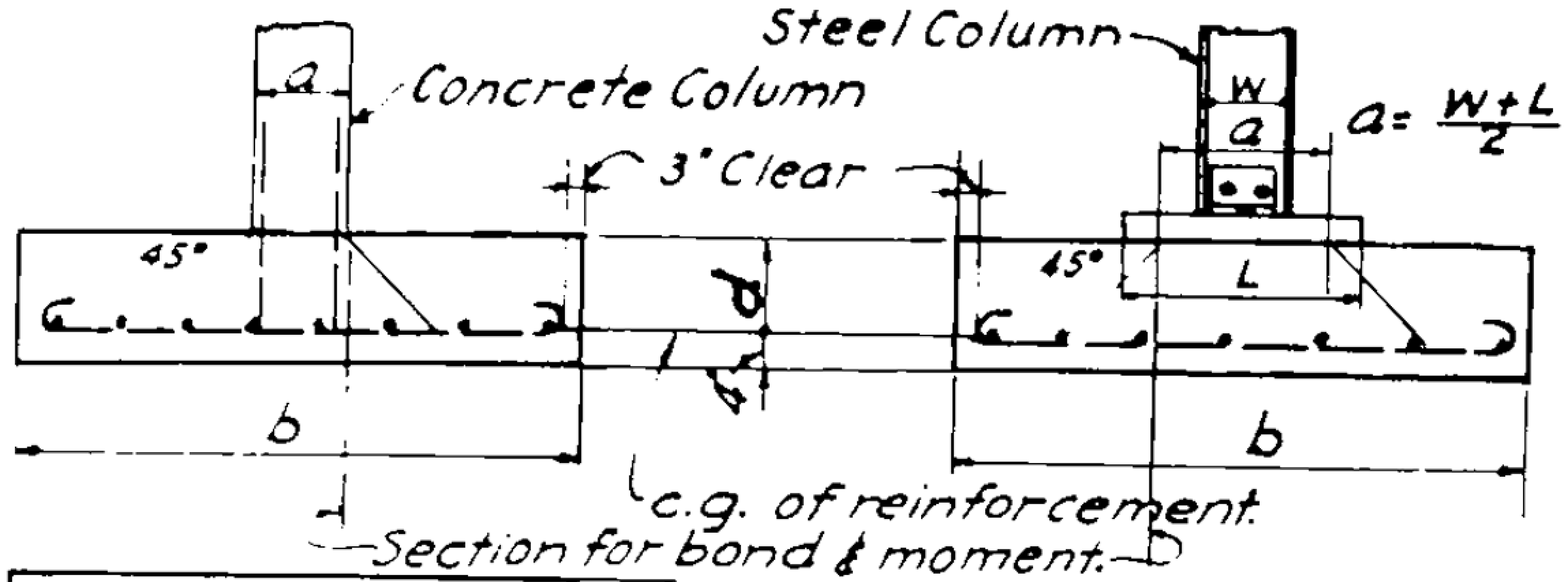
EXAMPLE:- Given:- Wall thickness = 12 inches ; Soil pressure = 6,000 lb. per sq. ft. ; and Wall load = 20,000 lb. per linear ft. of wall ; 2,000 lb. concrete.

Solution:- $2a = \frac{20{,}000}{6{,}000} - 1.0 = 2.33$ ft. = 28 in. $a = 14$ in.

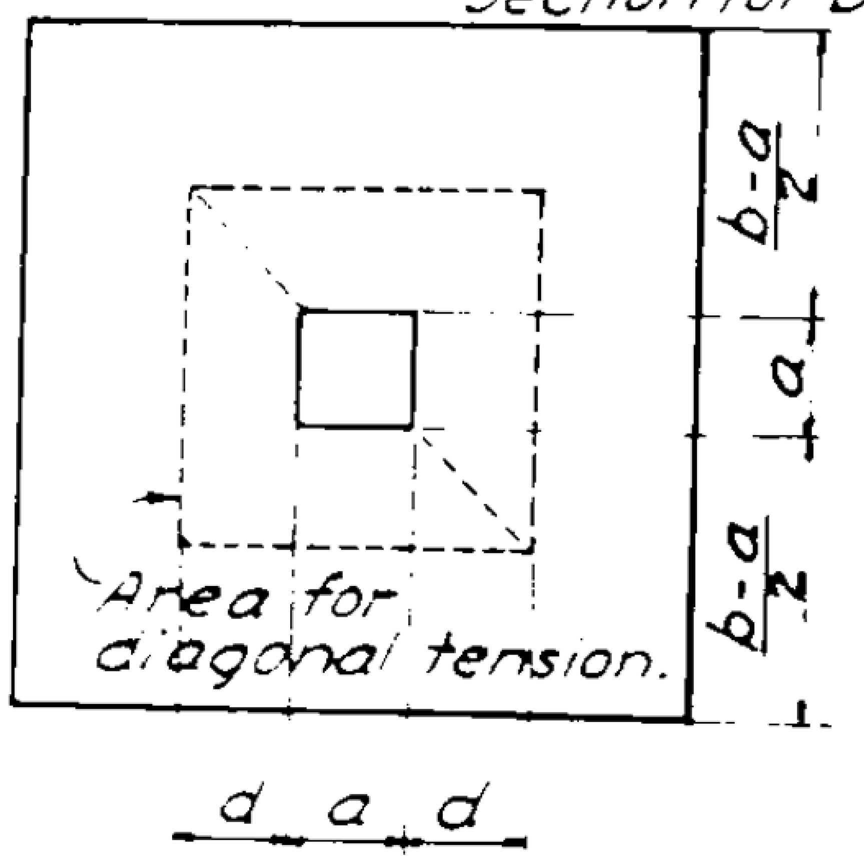
From diagram above for 2,000 lb. concrete, with $a = 14$ in. and 6,000 lb. soil
$t = 20.2$ in. or 21 in. for A.C.I. requirements.
$t = 23"$ for Joint Committee requirements.
$t = 25"$ for New York City Code requirements.

STRUCTURAL - FOUNDATIONS

SQUARE COLUMN FOOTINGS.*



DESIGN DATA.		
f'_c = 2,000 #/□"	f'_c = 3,000 #/□"	f'_c = 3,750 #/□"
f_c = 900 #/□"	f_c = 1,350 #/□"	f_c = 1,688 #/□"
f_s = 20,000 #/□"	f_s = 20,000 #/□"	f_s = 20,000 #/□"
v = 60 #/□"	v = 75 #/□"	v = 75 #/□"
u = 112.5 #/□"	u = 168 #/□"	u = 200 #/□"



1. Depth of footing is determined by diagonal tension.
$$v = \frac{(w-g)[b^2-(a+2d)^2]}{0.875 \times 4(a+2d)d}$$
Where: w = Soil pressure in #/□'. g = Weight of footing in #/□'.

2. $$\Sigma_o = \frac{(w-g)\,b(b-a)}{2} \times \frac{0.85}{u \times 0.875d}$$ Sum of perimeter of bars in inches.

3. $$\text{Moment} = \frac{(w-g)\,b(b-a)^2}{8}$$ (in ft. lbs.) (Check for f_c.)

4. $$A_s = \frac{M \times 12}{20{,}000 \times 0.875 \times d} \times 0.85$$ (in sq. inches.)

5. Reinforcement must satisfy both Σ_o and A_s.
6. Number of bars will vary directly with increased depth.
7. If size of bars is changed:-Provide equivalent perimeter when larger bars are used; and equivalent area when smaller bars are used.

TABLE A-SOIL BEARING VALUE. 2,000 LB. PER SQ. FT.

COLUMN LOAD IN 1000 LB.	b	d (IN)	f'_c=2000 #/□" MIN. a	f'_c=2000 #/□" REINF. EACH WAY	f'_c=3,000 #/□" MIN. a	f'_c=3,000 #/□" REINF. EACH WAY	f'_c=3750 #/□" MIN. a	f'_c=3750 #/□" REINF. EACH WAY
29	4'-0"	12	9"	6-½"φ	9"	5-½"φ	9"	5-½"φ
45	5'-0"	12	9"	9-½"φ	9"	6-½"φ	9"	5-½"φ
65	6'-0"	12	9"	13-½"φ	9"	9-½"φ	9"	6-⅝"φ
89	7'-0"	12	10"	17-½"φ	9"	10-⅝"φ	9"	10-⅝"φ
114	8'-0"	13	11"	22-½"φ	10"	10-¾"φ	9"	10-¾"φ
143	9'-0"	15	11"	19-⅝"φ	10"	12-¾"φ	10"	12-¾"φ
174	10'-0"	17	12"	21-⅝"φ	11"	15-¾"φ	10"	15-¾"φ
208	11'-0"	18	13"	20-¾"φ	11"	19-¾"φ	11"	19-¾"φ
245	12'-0"	20	14"	21-¾"φ	13"	21-¾"φ	12"	21-¾"φ
283	13'-0"	22	14"	23-¾"φ	13"	18-⅞"φ	13"	18-⅞"φ
324	14'-0"	24	14"	20-⅞"φ	14"	20-⅞"φ	13"	20-⅞"φ
369	15'-0"	25	16"	23-⅞"φ	15"	23-⅞"φ	14"	23-⅞"φ
416	16'-0"	27	16"	20-1"φ	15"	20-1"φ	14"	20-1"φ

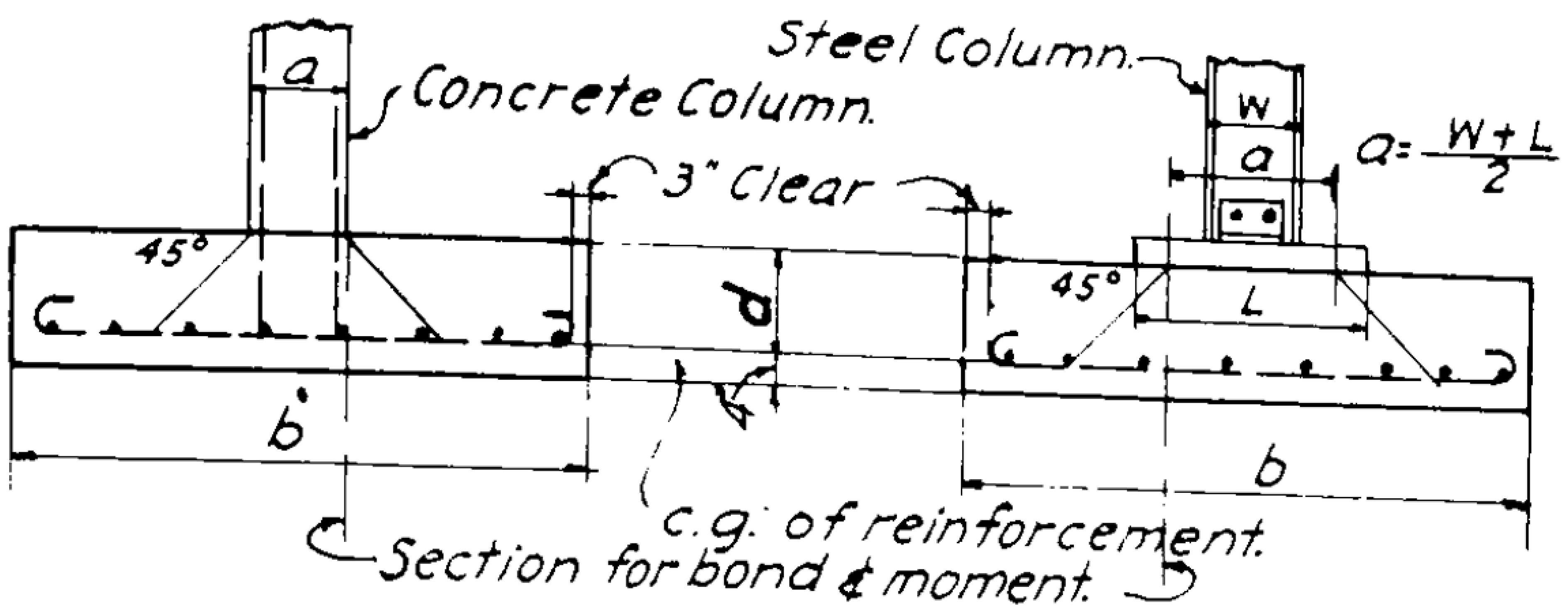
TABLE B-SOIL BEARING VALUE. 3,000 LB. PER SQ. FT.

COLUMN LOAD IN 1000 LB.	b	d (IN.)	f'_c=2000 #/□" MIN. a	f'_c=2000 #/□" REINF. EACH WAY	f'_c=3,000 #/□" MIN. a	f'_c=3,000 #/□" REINF. EACH WAY	f'_c=3750 #/□" MIN. a	f'_c=3750 #/□" REINF. EACH WAY
45	4'-0"	12"	9"	9-½"φ	9"	6-½"φ	9"	5-½"φ
70	5'-0"	12"	9"	14-½"φ	9"	9-½"φ	9"	8-½"φ
101	6'-0"	12"	10"	20-½"φ	9"	14-½"φ	9"	10-⅝"φ
136	7'-0"	14"	11"	24-½"φ	10"	13-⅝"φ	9"	9-¾"φ
176	8'-0"	16"	12"	27-½"φ	11"	12-¾"φ	10"	12-¾"φ
221	9'-0"	18"	13"	24-⅝"φ	11"	15-¾"φ	11"	11-⅞"φ
270	10'-0"	20"	14"	27-⅝"φ	12"	18-¾"φ	11"	14-⅞"φ
324	11'-0"	22"	16"	30-⅝"φ	14"	16-⅞"φ	13"	16-⅞"φ
382	12'-0"	24"	17"	26-¾"φ	15"	19-⅞"φ	13"	15-1"φ
444	13'-0"	26"	18"	28-¾"φ	15"	17-1"φ	14"	18-1"φ
510	14'-0"	28"	18"	26-⅞"φ	16"	20-1"φ	15"	20-1"φ
580	15'-0"	30"	20"	28-⅞"φ	18"	22-1"φ	17"	22-1"φ
654	16'-0"	32"	21"	31-⅞"φ	19"	25-1"φ	17"	20-1"□

*Based on A.C.I. Code - 1941.

STRUCTURAL - FOUNDATIONS

SQUARE COLUMN FOOTINGS.*



DESIGN DATA.		
f'_c = 2,000#/□"	f'_c = 3,000#/□"	f'_c = 3,750#/□"
f_c = 900#/□"	f_c = 1,350#/□"	f_c = 1,688#/□"
f_s = 20,000#/□"	f_s = 20,000#/□"	f_s = 20,000#/□"
v = 60#/□"	v = 75#/□"	v = 75#/□"
u = 112.5#/□"	u = 168#/□"	u = 200#/□"

TABLE A - SOIL BEARING VALUE. 4,000 LB. PER SQ. FT.

COLUMN LOAD IN 1000 LB.	b	d (IN.)	f'_c = 2,000#/□" MIN. a	f'_c = 2,000#/□" REINF. EACH WAY	f'_c = 3,000#/□" MIN. a	f'_c = 3,000#/□" REINF. EACH WAY	f'_c = 3,750#/□" MIN. a	f'_c = 3,750#/□" REINF. EACH WAY
34.2	3'-0"	12	9"	6-1/2"ϕ	9"	5-1/2"ϕ	9"	5-1/2"ϕ
46.5	3'-6"	12	9"	9-1/2"ϕ	9"	6-1/2"ϕ	9"	5-1/2"ϕ
60.8	4'-0"	12	9"	12-1/2"ϕ	9"	8-1/2"ϕ	9"	7-1/2"ϕ
77	4-6"	12	10"	12-5/8"ϕ	9"	10-1/2"ϕ	9"	9-1/2"ϕ
95	5'-0"	12	10"	15-5/8"ϕ	9"	13-1/2"ϕ	9"	11-1/2"ϕ
115	5'-6"	12	11"	18-5/8"ϕ	10"	15-1/2"ϕ	9"	11-5/8"ϕ
136	6'-0"	13	11"	20-5/8"ϕ	10"	17-1/2"ϕ	9"	12-5/8"ϕ
159	6'-6"	14	12"	22-5/8"ϕ	10"	15-5/8"ϕ	10"	14-5/8"ϕ
184	7'-0"	16	12"	23-5/8"ϕ	11"	15-5/8"ϕ	10"	11-3/4"ϕ
211	7'-6"	17	12"	24-5/8"ϕ	12"	13-3/4"ϕ	11"	12-3/4"ϕ
240	8'-0"	18	14"	26-5/8"ϕ	13"	15-3/4"ϕ	12"	14-3/4"ϕ
268	8'-6"	19	14"	27-5/8"ϕ	13"	16-3/4"ϕ	12"	16-3/4"ϕ
300	9'-0"	20	14"	29-5/8"ϕ	14"	17-3/4"ϕ	13"	13-7/8"ϕ
335	9'-6"	22	16"	29-5/8"ϕ	14	14-7/8"ϕ	13"	14-7/8"ϕ
369	10'-0"	23	16"	31-5/8"ϕ	15"	15-7/8"ϕ	14"	12-1"ϕ
405	10'-6"	24	16"	33-5/8"ϕ	15"	17-7/8"ϕ	14"	13-1"ϕ
443	11'-0"	25	18"	28-3/4"ϕ	15"	14-1"ϕ	14"	15-1"ϕ
484	11'-6"	27	18"	29-3/4"ϕ	16"	15-1"ϕ	15"	16-1"ϕ
524	12'-0"	28	18"	30-3/4"ϕ	16"	17-1"ϕ	15"	17-1"ϕ
610	13'-0"	30	20"	33-3/4"ϕ	17"	20-1"ϕ	16"	16-1"□
700	14'-0"	32	22"	38-3/4"ϕ	19"	18-1"□	17"	19-1"□
795	15'-0"	34	23"	33-7/8"ϕ	20"	21-1"□	18"	21-1"□
900	16'-0"	36	25"	30-1"ϕ	22"	23-1"□	20	24-1"□

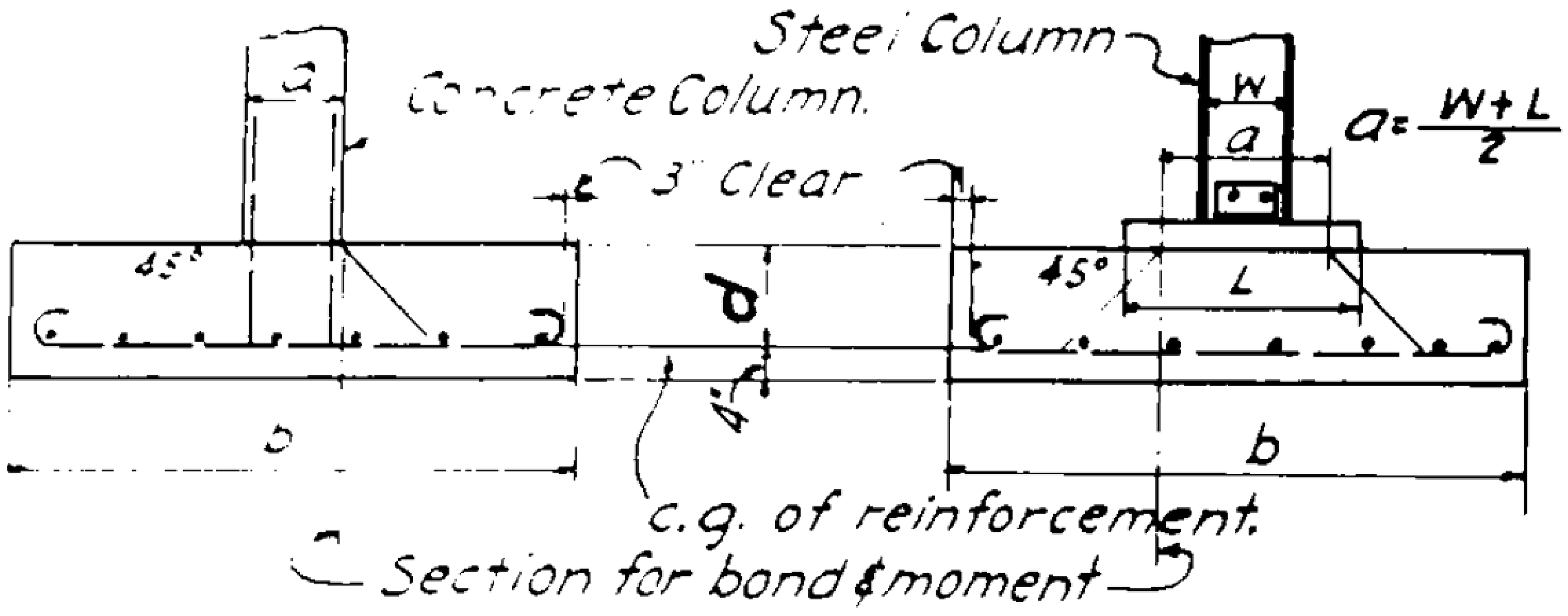
TABLE B - SOIL BEARING VALUE. 5,000 LB. PER SQ. FT.

COLUMN LOAD IN 1000 LB.	b	d (IN.)	f'_c = 2,000#/□" MIN. a	f'_c = 2,000#/□" REINF. EACH WAY	f'_c = 3,000#/□" MIN. a	f'_c = 3,000#/□" REINF. EACH WAY	f'_c = 3,750#/□" MIN. a	f'_c = 3,750#/□" REINF. EACH WAY
43.5	3'-0"	12	9"	8-1/2"ϕ	9"	5-1/2"ϕ	9"	5-1/2"ϕ
59	3'-6"	12	9"	11-1/2"ϕ	9"	8-1/2"ϕ	9"	6-1/2"ϕ
77	4'-0"	12	10"	12-5/8"ϕ	9"	10-1/2"ϕ	9"	9-1/2"ϕ
97	4'-6"	12	10"	15-5/8"ϕ	9"	13-1/2"ϕ	9"	11-1/2"ϕ
120	5'-0"	12	11"	18-5/8"ϕ	10"	16-1/2"ϕ	9"	14-1/2"ϕ
145	5'-6"	13	11"	17-3/4"ϕ	10	18-1/2"ϕ	10"	12-5/8"ϕ
172	6'-0"	14	12"	19-3/4"ϕ	11"	20-1/2"ϕ	10"	13-5/8"ϕ
202	6'-6"	16	13"	20-3/4"ϕ	11"	16-5/8"ϕ	10"	15-5/8"ϕ
232	7'-0"	17	13"	21-3/4"ϕ	12"	17-5/8"ϕ	11"	13-3/4"ϕ
266	7'-6"	19	14"	22-3/4"ϕ	12"	19-5/8"ϕ	12"	14-3/4"ϕ
301	8'-0"	20	15"	24-3/4"ϕ	14"	21-5/8"ϕ	13"	15-3/4"ϕ
340	8'-6"	21	16"	25-3/4"ϕ	14"	18-3/4"ϕ	13"	13-7/8"ϕ
380	9'-0"	22	17"	27-3/4"ϕ	15"	20-3/4"ϕ	14"	15-7/8"ϕ
420	9'-6"	24	17"	28-3/4"ϕ	15"	16-7/8"ϕ	14"	12-1"ϕ
464	10'-0"	25	18"	29-3/4"ϕ	16"	18-7/8"ϕ	14"	14-1"ϕ
520	10'-6"	26	19"	31-3/4"ϕ	16"	20-7/8"ϕ	15"	15-1"ϕ
560	11'-0"	27	19"	33-3/4"ϕ	17"	21-7/8"ϕ	16"	17-1"ϕ
610	11'-6"	28	21"	34-3/4"ϕ	18"	18-1"ϕ	17"	15-1"□
661	12'-0"	29	21"	36-3/4"ϕ	19"	20-1"ϕ	17"	16-1"□
770	13'-0"	31	22"	40-3/4"ϕ	20"	18-1"□	18"	19-1"□
890	14'-0"	33	26"	37-7/8"ϕ	22"	21-1"□	20"	22-1"□
1015	15'-0"	35	27"	39-7/8"ϕ	23"	25-1"□	21"	26-1"□
1150	16'-0"	37	28"	45-7/8"ϕ	24"	28-1"□	22"	29-1"□

* Based on A.C.I. Code - 1941.

STRUCTURAL - FOUNDATIONS

SQUARE COLUMN FOOTINGS.*



DESIGN DATA.		
f'_c = 2,000#/□"	f'_c = 3,000#/□"	f'_c = 3,750#/□"
f_c = 900#/□"	f_c = 1,350#/□"	f_c = 1,688#/□"
f_s = 20,000#/□"	f_s = 20,000#/□"	f_s = 20,000#/□"
v = 60#/□"	v = 75#/□"	v = 75#/□"
u = 112.5#/□"	u = 168#/□"	u = 200#/□"

TABLE A - SOIL BEARING VALUE. 6,000 LB. PER SQ. FT.

COLUMN LOAD IN 1000 LB.	b	d (IN.)	f'_c = 2,000#/□" MIN. a	f'_c = 2,000#/□" REINF. EACH WAY	f'_c = 3,000#/□" MIN. a	f'_c = 3,000#/□" REINF. EACH WAY	f'_c = 3,750#/□" MIN. a	f'_c = 3,750#/□" REINF. EACH WAY
52	3'-0"	12	9"	9 - 1/2"φ	9"	6 - 1/2"φ	9"	6 - 1/2"φ
71	3'-6"	2	9"	10 - 5/8"φ	9"	9 - 1/2"φ	9"	8 - 1/2"φ
93	4'-0"	12	10"	4 - 5/8"φ	9"	12 - 1/2"φ	9"	10 - 1/2"φ
[illegible]8	4'-6"	2	11"	17 - 5/8"φ	10"	15 - 1/2"φ	9"	13 - 1/2"φ
[illegible]45	5'-0"	13	11"	17 - 3/4"φ	10"	18 - 1/2"φ	10"	15 - 1/2"φ
[illegible]75	5'-6"	14	12"	9 - 3/4"φ	11"	19 - 1/2"φ	10"	13 - 5/8"φ
208	6'-0"	15	13"	21 - 3/4"φ	11"	17 - 5/8"φ	11"	15 - 5/8"φ
243	6'-6"	17	14"	22 - 3/4"φ	12"	18 - 5/8"φ	11"	17 - 5/8"φ
28[illegible]	7'-0"	18	15"	24 - 3/4"φ	13"	20 - 5/8"φ	13"	14 - 3/4"φ
322	7'-6"	20	16"	24 - 3/4"φ	14"	21 - 5/8"φ	13"	15 - 3/4"φ
365	8'-0"	21	16"	27 - 3/4"φ	14"	18 - 3/4"φ	14"	13 - 7/8"φ
410	8'-6"	22	17"	29 - 3/4"φ	15"	20 - 3/4"φ	14"	15 - 7/8"φ
460	9'-0"	23	18"	31 - 3/4"φ	16"	22 - 3/4"φ	15"	16 - 7/8"φ
510	9'-6"	25	18"	32 - 3/4"φ	16"	19 - 7/8"φ	15"	11 - 1"□
563	10'-0"	26	20"	34 - 3/4"φ	17"	20 - 7/8"φ	15"	12 - 1"□
620	10'-6"	27	21"	35 - 3/4"φ	18"	14 - 1"□	17"	14 - 1"□
680	11'-0"	28	21"	38 - 3/4"φ	19"	15 - 1"□	17"	15 - 1"□
740	11'-6"	29	22"	40 - 3/4"φ	19"	16 - 1"□	18"	17 - 1"□
805	12'-0"	30	23"	42 - 3/4"φ	20"	18 - 1"□	18"	18 - 1"□
940	13'-0"	33	25"	38 - 7/8"φ	22"	21 - 1"□	20"	21 - 1"□
1080	14'-0"	36	26"	40 - 7/8"φ	23"	23 - 1"□	21"	24 - 1"□
1230	15'-0"	38	29"	43 - 7/8"φ	25"	27 - 1"□	23"	27 - 1"□
1400	16'-0"	40	30"	49 - 7/8"φ	26"	31 - 1"□	24"	32 - 1"□

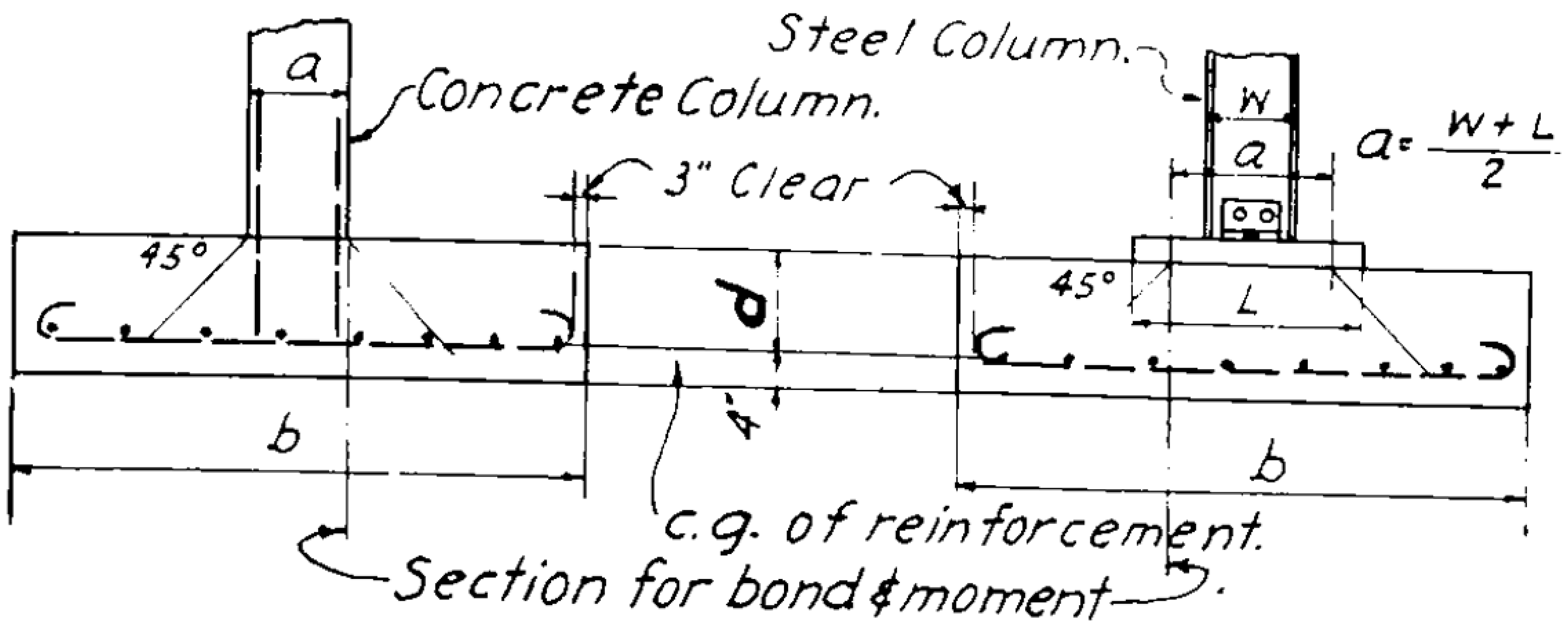
TABLE B - SOIL BEARING VALUE. 8,000 LB. PER SQ. FT.

COLUMN LOAD IN 1000 LB.	b	d (IN.)	f'_c = 2,000#/□" MIN. a	f'_c = 2,000#/□" REINF. EACH WAY	f'_c = 3,000#/□" MIN. a	f'_c = 3,000#/□" REINF. EACH WAY	f'_c = 3,750#/□" MIN. a	f'_c = 3,750#/□" REINF. EACH WAY
70	3'-0"	12	9"	8 - 3/4"φ	9"	8 - 1/2"φ	9"	7 - 1/2"φ
96	3'-6"	12	10"	11 - 3/4"φ	9"	10 - 5/8"φ	9"	10 - 1/2"φ
125	4'-0"	12	11"	13 - 7/8"φ	10"	12 - 5/8"φ	9"	13 - 1/2"φ
158	4'-6"	12	12"	16 - 7/8"φ	10"	16 - 5/8"φ	10"	14 - 5/8"φ
194	5'-0"	14	12"	18 - 7/8"φ	11"	17 - 5/8"φ	10"	15 - 5/8"φ
235	5'-6"	15	13"	20 - 7/8"φ	12"	19 - 5/8"φ	11"	16 - 5/8"φ
280	6'-0"	17	14"	21 - 7/8"φ	12"	20 - 5/8"φ	11"	18 - 5/8"φ
327	6'-6"	18	16"	23 - 7/8"φ	14"	22 - 5/8"φ	13"	19 - 5/8"φ
378	7'-0"	19	17"	25 - 7/8"φ	15"	24 - 5/8"φ	13"	18 - 3/4"φ
432	7'-6"	21	17"	27 - 7/8"φ	15"	26 - 5/8"φ	14"	19 - 3/4"φ
492	8'-0"	22	18"	29 - 7/8"φ	16"	23 - 3/4"φ	15"	21 - 3/4"φ
553	8'-6"	24	19"	30 - 7/8"φ	17"	24 - 3/4"φ	15"	18 - 7/8"φ
620	9'-0"	25	21"	32 - 7/8"φ	18"	26 - 3/4"φ	17"	20 - 7/8"φ
690	9'-6"	26	22"	34 - 7/8"φ	19"	29 - 3/4"φ	18"	14 - 1"□
760	10'-0"	28	22"	35 - 7/8"φ	19"	24 - 7/8"φ	18"	15 - 1"□
835	10'-6"	29	23"	38 - 7/8"φ	20"	26 - 7/8"φ	19"	16 - 1"□
915	11'-0"	30	26"	39 - 7/8"φ	23"	28 - 7/8"φ	21"	18 - 1"□
1000	11'-6"	32	27"	40 - 7/8"φ	23"	19 - 1"□	22"	19 - 1"□
1090	12'-0"	33	28"	42 - 7/8"φ	24"	20 - 1"□	22"	21 - 1"□
1270	13'-0"	36	29"	45 - 7/8"φ	25"	24 - 1"□	23"	25 - 1"□
1460	14'-0"	39	30"	49 - 7/8"φ	26"	28 - 1"□	24"	29 - 1"□
1670	15'-0"	42	32"	51 - 7/8"φ	28"	32 - 1"□	26"	32 - 1"□
1900	16'-0"	44	34"	56 - 7/8"φ	29"	37 - 1"□	27"	37 - 1"□

* Based on A.C.I. Code - 1941.

STRUCTURAL - FOUNDATIONS

SQUARE COLUMN FOOTINGS.*



DESIGN DATA.

f'_c = 2,000#/□"	f'_c = 3,000#/□"	f'_c = 3,750#/□"
f_c = 900#/□"	f_c = 1,350#/□"	f_c = 1,688#/□"
f_s = 20,000#/□"	f_s = 20,000#/□"	f_s = 20,000#/□"
v = 60#/□"	v = 75#/□"	v = 75#/□"
u = 112.5#/□"	u = 168#/□"	u = 200#/□"

TABLE A - SOIL BEARING VALUE. 12,000 LB. PER SQ. FT.

COLUMN LOAD IN 1000 LB.	b	d (IN.)	f'_c = 2,000#/□"		f'_c = 3,000#/□"		f'_c = 3,750#/□"	
			MIN. a	REINF. EACH WAY	MIN. a	REINF. EACH WAY	MIN. a	REINF. EACH WAY
106	3'-0"	12	10"	7-1"□	9"	8-3/4"φ	9"	9-5/8"φ
145	3'-6"	12	11"	10-1"□	10"	11-3/4"φ	10"	10-3/4"φ
188	4'-0"	12	12"	13-1"□	10"	13-7/8"φ	10"	13-3/4"φ
240	4'-6"	14	13"	14-1"□	11"	14-7/8"φ	11"	14-3/4"φ
295	5'-0"	15	14"	16-1"□	13"	16-7/8"φ	13"	16-3/4"φ
356	5'-6"	17	16"	17-1"□	14"	19-7/8"φ	13"	19-3/4"φ
423	6'-0"	18	17"	20-1"□	15"	20-7/8"φ	14"	20-3/4"φ
495	6'-6"	20	18"	21-1"□	16"	21-7/8"φ	15"	21-3/4"φ
573	7'-0"	21	19"	23-1"□	17"	23-7/8"φ	16"	23-3/4"φ
657	7'-6"	23	21"	24-1"□	18"	24-7/8"φ	17"	24-3/4"φ
747	8'-0"	24	22"	26-1"□	19"	26-7/8"φ	18"	28-3/4"φ
840	8'-6"	26	23"	27-1"□	20"	28-7/8"φ	19"	23-7/8"φ
940	9'-0"	27	26"	29-1"□	23"	29-7/8"φ	21"	25-7/8"φ
1050	9'-6"	28	27"	31-1"□	24"	32-7/8"φ	22"	29-7/8"φ
1158	10'-0"	30	28"	32-1"□	24"	33-7/8"φ	23"	19-1"□
1275	10'-6"	32	29"	33-1"□	25"	34-7/8"φ	23"	21-1"□
1390	11'-0"	33	30"	36-1"□	26"	37-7/8"φ	24"	23-1"□
1525	11'-6"	35	31"	37-1"□	27"	40-7/8"φ	25"	25-1"□
1657	12'-0"	36	32"	39-1"□	28"	27-1"□	26"	28-1"□
1940	13'-0"	40	33"	42-1"□	29"	32-1"□	27"	32-1"□
2240	14'-0"	42	37"	45-1"□	33"	36-1"□	30	37-1"□
2560	15'-0"	46	39"	47-1"□	34"	41-1"□	32	43-1"□
2900	16'-0"	48	41"	51-1"□	36"	47-1"□	33	49-1"□

TABLE B - SOIL BEARING VALUE. 16,000 LB. PER SQ. FT.

COLUMN LOAD IN 1000 LB.	b	d (IN.)	f'_c = 2,000#/□"		f'_c = 3,000#/□"		f'_c = 3,750#/□"	
			MIN. a	REINF. EACH WAY	MIN. a	REINF. EACH WAY	MIN. a	REINF. EACH WAY
142	3'-0"	12	11"	9-1"□	10"	3-7/8"φ	9"	8-7/8"φ
194	3'-6"	14	12"	11-1"□	11"	11-7/8"φ	10"	10-7/8"φ
252	4'-0"	15	14"	13-1"□	12"	9-1"□	11"	12-7/8"φ
319	4'-6"	16	16"	15-1"□	14"	11-1"□	13"	14-7/8"φ
393	5'-0"	18	17"	17-1"□	15"	12-1"□	14"	15-7/8"φ
475	5'-6"	20	18"	19-1"□	16"	13-1"□	15"	16-7/8"φ
565	6'-0"	21	20"	21-1"□	18"	15-1"□	16"	18-7/8"φ
662	6'-6"	23	21"	23-1"□	19"	16-1"□	17"	19-7/8"φ
765	7'-0"	25	23"	25-1"□	19"	17-1"□	19"	20-7/8"φ
880	7'-6"	26	25"	27-1"□	20"	19-1"□	20"	23-7/8"φ
1000	8'-0"	27	27"	29-1"□	22"	20-1"□	21"	26-7/8"φ
1127	8'-6"	28	28"	32-1"□	24"	22-1"□	22"	28-7/8"φ
1260	9'-0"	29	29"	35-1"□	25"	25-1"□	23"	21-1"□
1405	9'-6"	30	30"	38-1"□	26"	26-1"□	24"	23-1"□
1555	10'-0"	32	31"	40-1"□	27"	28-1"□	25"	24-1"□
1712	10'-6"	33	32"	42-1"□	28"	29-1"□	26"	26-1"□
1880	11'-0"	35	33"	44-1"□	29"	30-1"□	27"	28-1"□
2045	11'-6"	37	34"	45-1"□	30"	31-1"□	28"	30-1"□
2230	12'-0"	38	38"	47-1"□	33"	33-1"□	30"	33-1"□
2615	13'-0"	42	40"	50-1"□	34"	36-1"□	32"	38-1"□
3020	14'-0"	45	42"	54-1"□	36"	43-1"□	34"	44-1"□
3460	15'-0"	48	45"	59-1"□	39"	49-1"□	35"	52-1"□
3930	16'-0"	51	48"	63-1"□	42"	56-1"□	37"	59-1"□

*Based on A.C.I. Code - 1941.

STRUCTURAL - FOUNDATIONS

RECTANGULAR COLUMN FOOTINGS - USING TABLES FOR SQUARE COLUMN FOOTINGS.

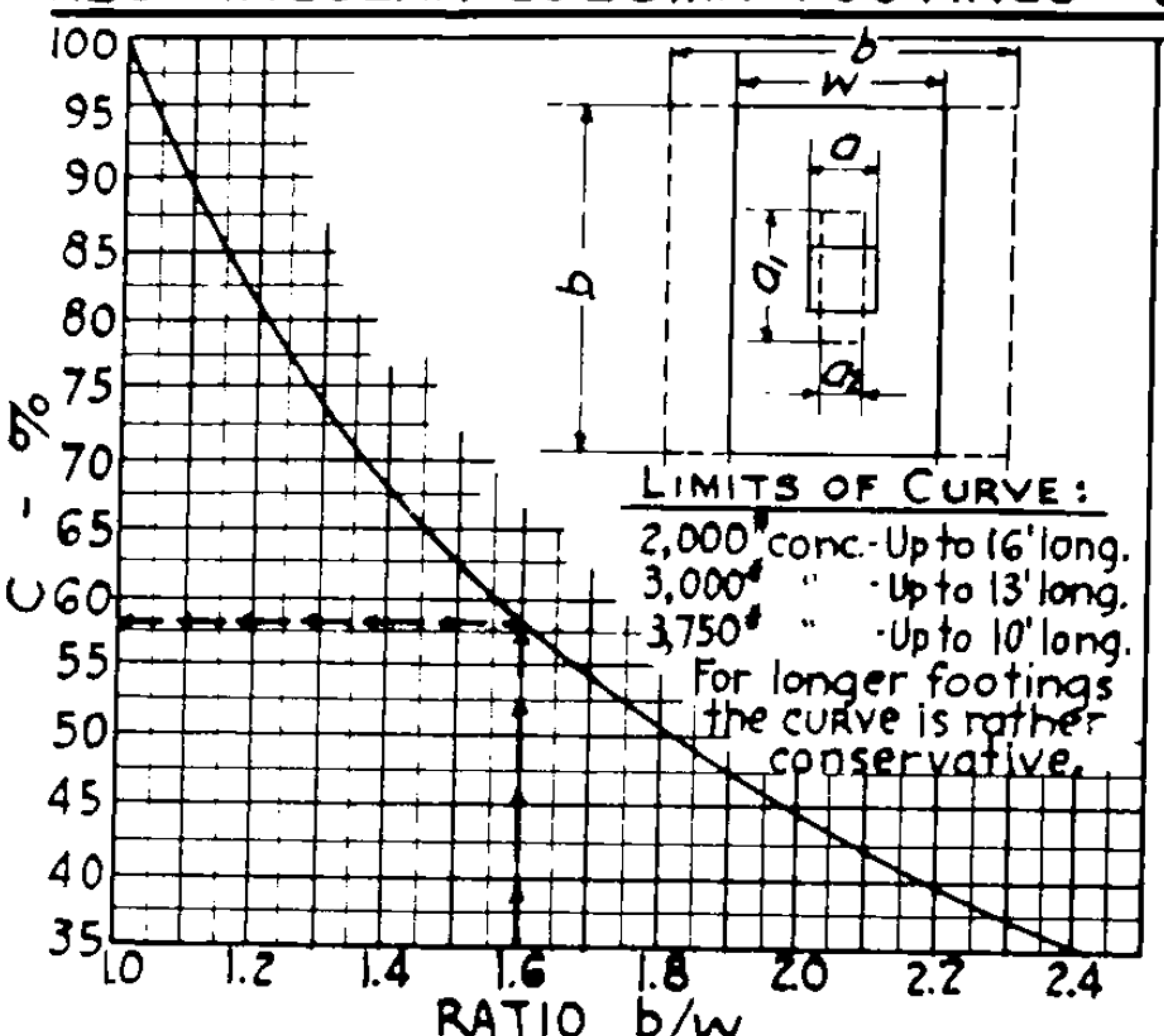


FIG.A-VALUE OF "C" FOR TRANSVERSE REINFORCEMENT.

GIVEN: Footing 7'-6"x12'; 3,000 lb. concrete; soil pressure = 12,000 lb./sq.ft.
REQUIRED: Depth of footing and reinforcement.
SOLUTION: From Table A, page 2-55 for 12' square footing depth = 36 in.

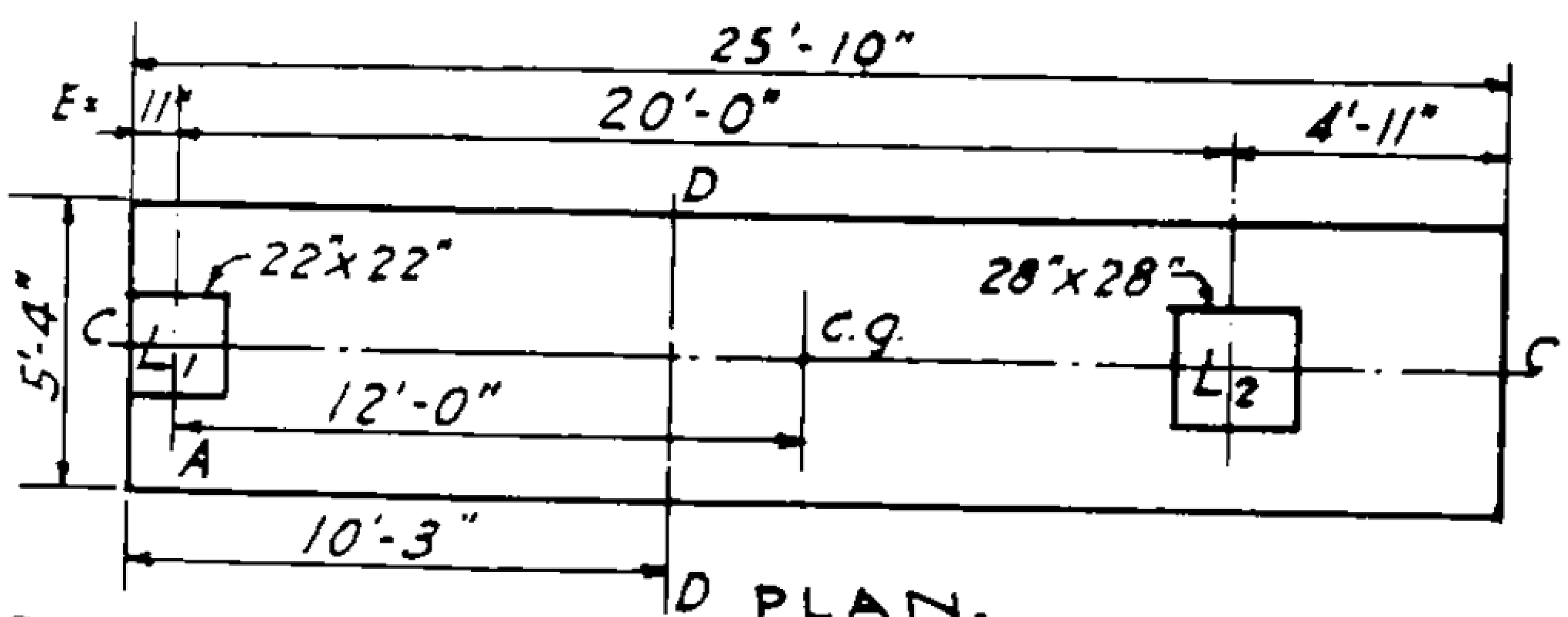
Longitudinal reinforcement = $\frac{7.5}{12}$ x 27-1"□ bars = 17-1"□ bars.

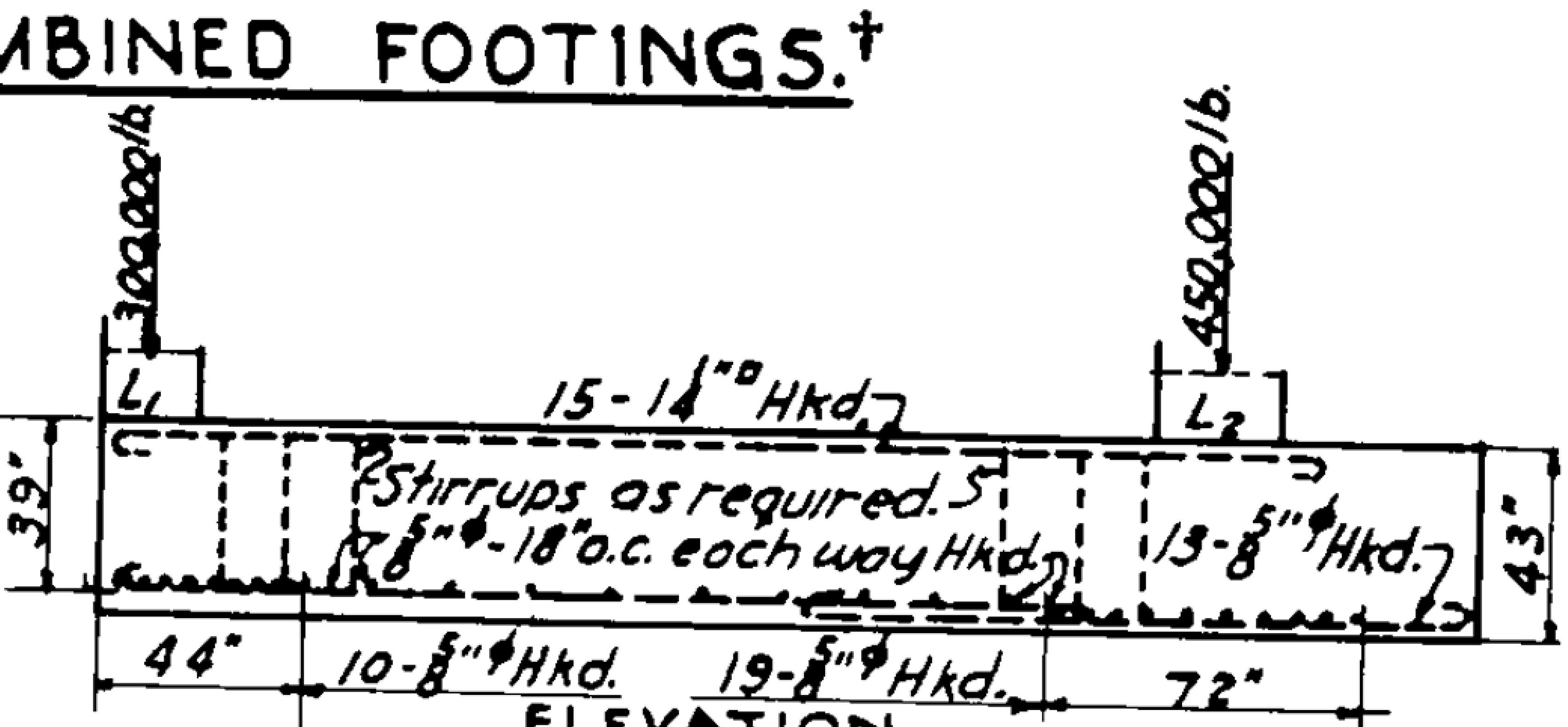
Transverse reinforcement: From Fig. A at left, C = 58% for b/W = 1.6. 27 x 58% = 15.6. Use 16-1"□ bars.

EFFECT OF RECTANGULAR COLUMNS ON SQUARE OR RECTANGULAR FOOTINGS.

Let a = One side of square column given in Square Column Footing Tables; a_1 = long side of rectangular Col. a_2 = short side of rectangular Col.
Select reinforcement parallel to a_1 from square footing whose size is = $b - a_1 + a$.
Select reinforcement parallel to a_2 from square footing whose size is = $b + a - a_2$.

RECTANGULAR COMBINED FOOTINGS.†



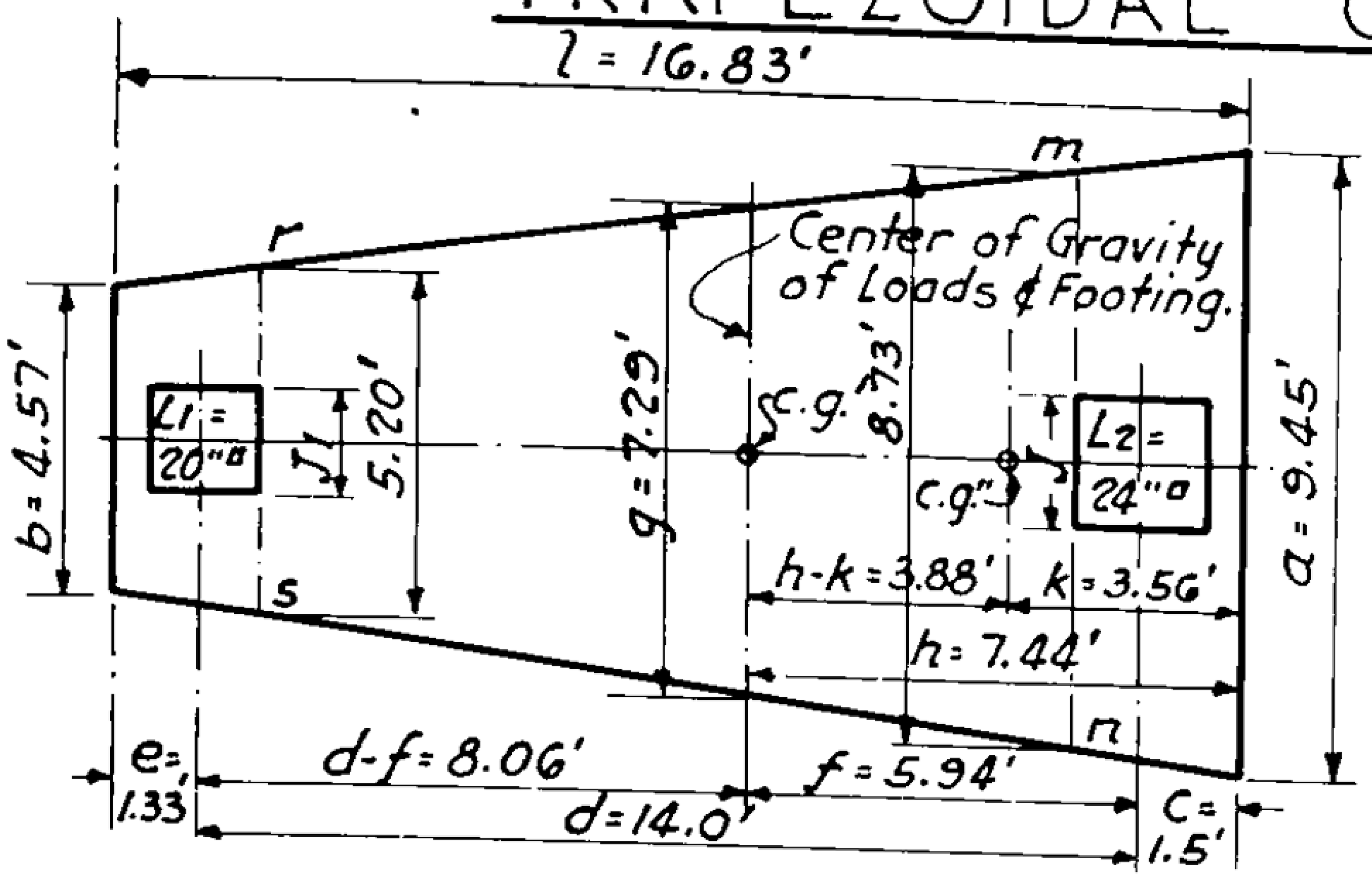


GIVEN: Column L_1 is 22" square, load of 300,000 lb. Column L_2 is 28" square, load of 450,000 lb. E = 11"; c to c of columns is 20'-0". Allowable soil pressure is 6,000 lb./sq.ft. 2,000 lb. concrete with intermediate grade steel @ 20,000 p.s.i.
REQUIRED: Size of footing and necessary reinforcement.
Center of gravity of loads from A = $\frac{450,000 \times 20}{300,000 + 450,000} = 12.0'$. This should also be the center of the footing area. Then the required length of footing = $2 \times 12 + \frac{11}{12} \times 2$ = 25'-10". Assume the footing weight is 500 lb./sq.ft. The net bearing value = 6,000 - 500 = 5,500 lb./sq.ft. Required area = $\frac{750,000}{5,500}$ = 136.5 sq.ft. Required width = $\frac{137}{25.83}$ = 5.3'
Maximum moment at line of zero shear, D-D, from left end obtained by equation is $300,000 = 5,500 \times 5.3X$, whence $X = 10.3'$. $M = 300,000 \times 9.4 - 5,500 \times 5.3 \times \frac{10.3^2}{2} = 1,275,000$ ft.lb. ∴ For rectangular beam $d = \sqrt{\frac{1,275,000 \times 12}{157 \times 5.3 \times 12}}$ = 39" or a total depth of 43". The assumed weight of footing is sufficiently exact.
Then from the formula $A_s = \frac{M}{f_s jd} = \frac{1,275,000 \times 12}{20,000 \times .866 \times 39}$ = 22.7 sq.in. = 15-1¼"□ rods hooked each end.
Next investigate bond at columns L_1 and L_2. Shear at column L_1 = 300,000 - 5,500 x 5.3 x 1.83 = 247,000 lb.
*Unit shear = $\frac{247,000}{64 \times .866 \times 39}$ = 114 lb./sq.in. requiring stirrups. Then no. of rods for bond, $u = \frac{V}{\Sigma_o jd} = \frac{247,000}{5 \times 150 \times .866 \times 39}$ = 10 rods.
Shear at column L_2 = 450,000 - 5,500 x 5.3 x 6.08 = 273,000 lb. *Unit shear = $\frac{273,000}{64 \times .866 \times 39}$ = 126 lb./sq.in. requiring stirrups.
No. of 1¼"□ rods for bond = $\frac{273,000}{5 \times 150 \times .866 \times 39}$ = 11. Therefore steel for moment governs.
Between column L_2 and the right end of footing the moment is positive and the bottom bars are determined by the moment at the right face of the column. $M = 5.3 \times 5,500 \times 3.75 \times \frac{3.75}{2}$ = 206,000 ft.lb.
$A_s = \frac{206,000 \times 12}{20,000 \times .866 \times 39}$ = 3.7 sq.ft. Use 13-5/8"φ rods hooked each end. Shear = 5.3 x 5,500 x 3.75 = 109,500 lb. No. of 5/8"φ rods for bond = $\frac{109,500}{196 \times 150 \times .866 \times 39}$ = 11 sq.in. ∴ Use 13-5/8"φ **rods.**
Transverse reinforcement is calculated in a similar manner. With the depth of slab used, the transverse bars are hardly needed as the projection beyond the column is only about ½ the depth of the slab. The theoretical steel area along the line C-C for column L_2 is as follows: Moment = $\frac{450,000}{5.3} \times \frac{1.5^2}{2}$ = 96,000 ft.lb.
$A_s = \frac{96,000 \times 12}{20,000 \times .866 \times 39}$ = 1.7 sq.in. $\Sigma_o = \frac{190,000}{150 \times .866 \times 39}$ = 37.5 sq.in. Therefore use 19-5/8"φ rods. Similarly steel may be figured for column L_1 and found to be 10-5/8"φ bars.
It is customary to place a few rods in the bottom of the footing as shown in the sketch (5/8"φ-18" o.c. each way) to provide for any possible defects in the bed of the foundation.

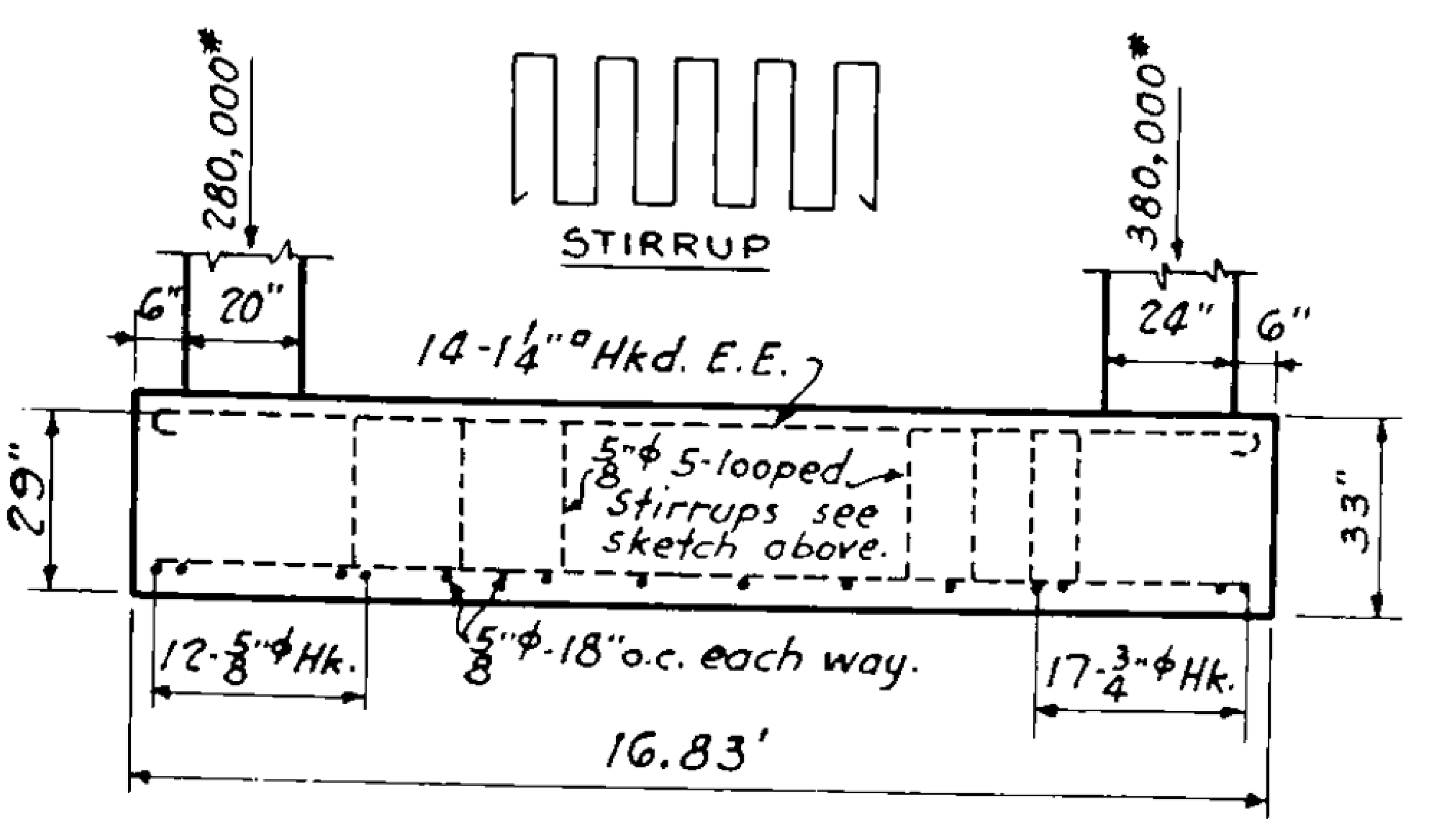
* Some authorities recommend figuring shear at a distance from face of column equal to the effective depth of footing.

† Adapted from Principles of Reinforced Conc. Construction by Turneaure & Maurer.

TRAPEZOIDAL COMBINED FOOTING



PLAN



ELEVATION

GIVEN:- Column L_1 is 20" square, load of 280,000#; Column L_2 is 24" square, load of 380,000#; e=1.33'; c=1.5'; c. to c. of columns is 14'-0"; allowable soil pressure is 6,000#/□'; 2,000# concrete with intermediate grade steel @ 20,000#/□".

REQUIRED:- Size of footing and necessary reinforcement.

Let A' = Area of entire footing; P' = allowable soil pressure minus weight of footing; A'' = Area of portion of footing from center of gravity to wider end.

(1)- $A' = \frac{L_1+L_2}{P'} = \frac{280,000+380,000}{5,600} = 118$□'. (2)- Center of gravity (c.g.') of loads which must coincide with center of gravity of footing for uniform soil pressure = $f = \frac{L_1 d}{L_2+L_1} = \frac{280,000\times 14}{660,000} = 5.94$ feet.

∴ $h = f + c = 5.94' + 1.5' = 7.44$ feet.

(3)- From formula $a = \frac{A'(4l-6h)}{l^2} = \frac{118(4\times 16.83 - 6\times 7.44)}{16.83^2} = 9.45$ feet.

(4)- From formula for area of trapezoid $A' = \frac{a+b}{2}(l)$, then $b = \frac{2A'}{l} - a = \frac{118\times 2}{16.83} - 9.45 = 4.57$ feet.

(5)- $g = a-(a-b)\frac{h}{l} = 9.45-(9.45-4.57)\frac{7.44}{16.83} = 7.29$ feet. (6)- c.g." or $k = \frac{h}{3}\left(\frac{a+2g}{a+g}\right) = \frac{7.44}{3}\left(\frac{9.45+2\times 7.29}{9.45+7.29}\right) = 3.56$ feet.

(7)- $A'' = \frac{g+a}{2}\times h = \frac{7.29+9.45}{2}\times 7.44 = 62.3$ square feet.

(8) Maximum Moment $= L_2\times f - A''(h-k)P' = 380,000\times 5.94 - 62.3\times 3.88\times 5600 = 905,000$ ft. lbs.

From formula for rectangular beams $d = \sqrt{\frac{M}{Kg}} = \sqrt{\frac{905,000\times 12}{157\times 12\times 7.29}} = 28.1$ use 29" or total depth of 33".

Then from formula $A_s = \frac{M}{f_s jd} = \frac{905,000\times 12}{20,000\times .866\times 29} = 21.7$ sq. in. or 14-1¼"□ hooked each end.

Next investigate bond at Cols. L_1 and L_2.

Shear at Col. $L_2 = 380,000 - \frac{8.73+9.45}{2}\times 2.5\times 5600 = 253,000$ lbs. Bond $u = \frac{V}{\Sigma_0 jd}$ or No. of rods $= \frac{253,000}{5\times .866\times 29\times 150} = 14$.

∴ 14-1¼"□ rods hooked at each end is satisfactory.

Shear at Col. $L_1 = 280,000 - \frac{4.57+5.20}{2}\times 2.17\times 5,600 = 221,000$ lbs., which is less than shear at Col. L_2.

Transverse reinforcement is provided to prevent bending of the projection of the footing. Considering Col. L_2, and assuming the width of the distributing beam as 3'-6", the load $= \frac{L_2}{2}\times\frac{a-j}{a} = \frac{380,000}{2}\times\frac{9.45-2.0}{9.45} =$ 149,500 lbs. Then Mom = load $\times \frac{a-j}{4} = 149,500\times\frac{9.45-2.0}{4} = 278,000$ ft. lbs. Then $d = \sqrt{\frac{278,000\times 12}{157\times 3.5\times 12}} = 22.5$, which is smaller than depth of footing; and $A_s = \frac{278,000\times 12}{20,000\times .866\times 29} = 6.7$□" or 16-¾"φ hooked each end.

For bond $u = \frac{V}{\Sigma_0 jd}$ or No. of rods $= \frac{149,500}{2.36\times .866\times 150\times 29} = 17$. Thus the number for bond controls. ∴ use 17-¾"φ Hooked ea. end

In the same manner the distributing steel for column L_1 is determined. Load $= \frac{280,000}{2}\times\frac{4.57-1.67}{4.65} = 88,700$ lbs.

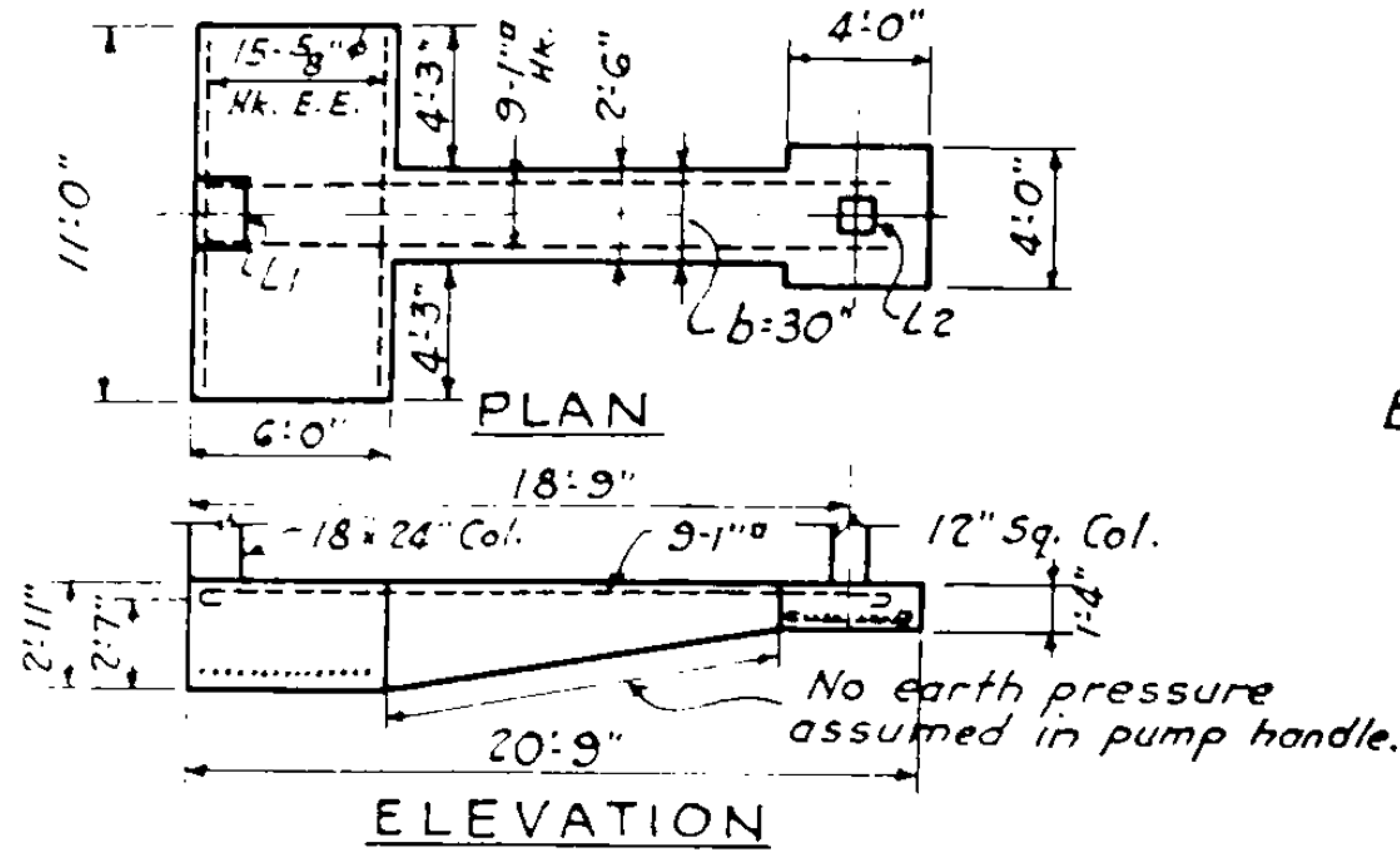
Mom. $= 88,700\times\frac{4.57-1.67}{4} = 64,300$ ft. lbs. and $A_s = \frac{64,300\times 12}{20,000\times 29\times .866} = 1.53$ or 6-⅝"φ.

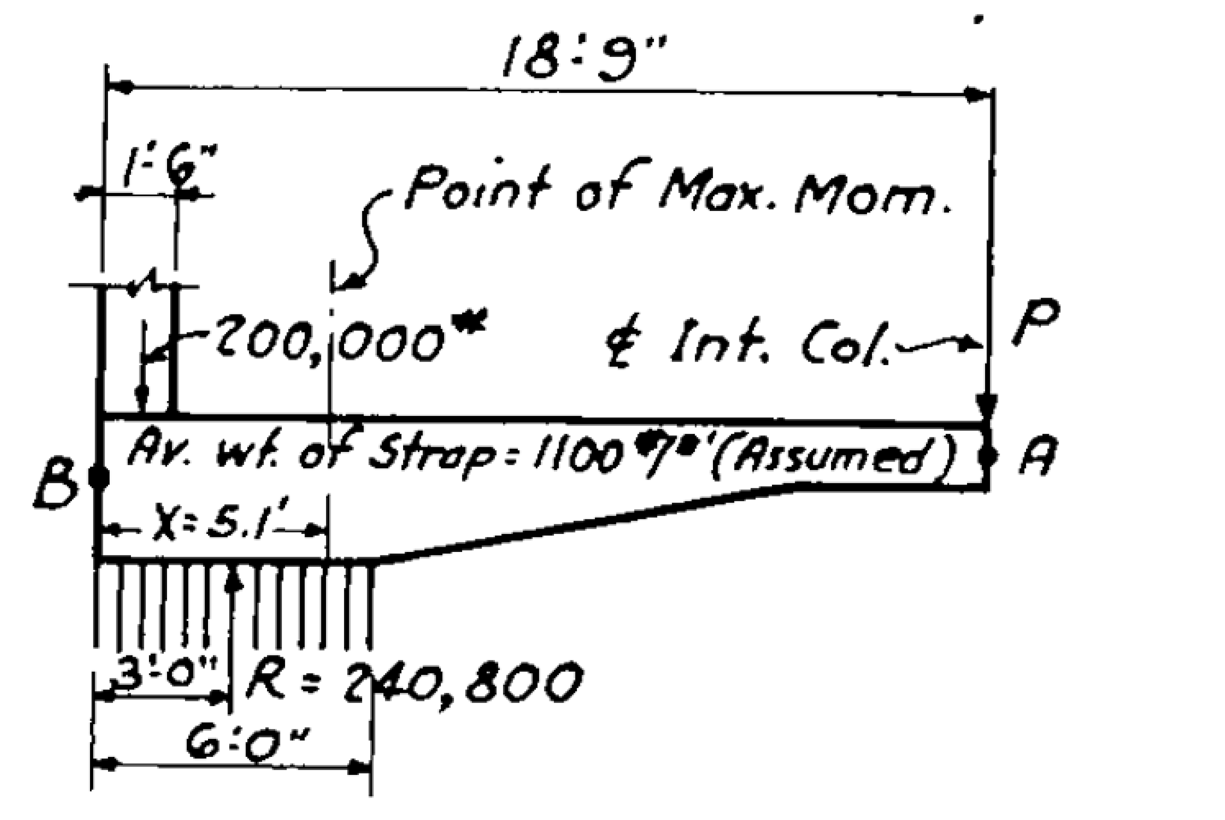
For bond the no. of rods $= \frac{88,700}{1.96\times .866\times 150\times 29} = 12$ ∴ use 12-⅝"φ hooked each end.

Diagonal tension reinforcement is not needed in the distribution beams since each distributing beam and column has a similar load to that of a single footing. For such footings the intensity of shearing stress as a measure of diagonal tension is computed on a section at a distance from the face of the column equal to the depth of the footing to the steel. Compute the shear, in the longitudinal direction, on a section at the supports as mn and rs. The spacing and size of the stirrups are determined as in a single beam. Place rods in the bottom of footing as shown in sketch (⅝"φ-18"o.c. each way) to provide for possible defects in the foundation bed.

STRUCTURAL - FOUNDATIONS

CANTILEVER FOOTING (COMMONLY KNOWN AS PUMP HANDLE FOOTING)†





EXTERNAL FORCES AS A FREE BODY

GIVEN: Column $L_1 = 18'' \times 24''$, load of 200,000#; Column $L_2 = 12''$ square, load of 60,000# of which 30,000# is Dead Load; 18'9" from ℄ of interior col. L_2 to the outside face of exterior column L_1: allowable soil pressure of 4,000 lbs. per sq. ft.; 2,000 lb. concrete with intermediate grade reinforcement.

REQUIRED:- Size and reinforcement of the eccentrically loaded footing and the connecting beam or strap.

The interior column footing is designed in the usual manner and it is assumed this design has been made.

The area required for the exterior column load, allowing about 30 per cent for the weight of the footing and strap. =

$260{,}000/4{,}000 = 65.0$ sq. ft. A base 6'-0" × 11'-0" is selected.

Considering the strap as a free body with the external forces as illustrated above, the reaction R is determined by taking moments about A, as follows:- $-200{,}000 \times 18 - 1100 \times 18.75 \times 18.75/2 + R \times 15.75 = 0$, from which $R = 240{,}800$.

The downward force P is determined by taking moments about B, as follows:- $200{,}000 \times .75 + 1100 \times 18.75 \times 18.75/2 + P \times 18.75 = 240{,}800 \times 3$, from which $P = 20{,}200$. Since P is less than the dead load (30,000#) of Col. L_2, there will be no uplift at column L_2.

The maximum moment in the strap occurs at the point of zero shear at a distance X from B as follows:- $-200{,}000 + 240{,}800/6\,X - 1100X = 0$, from which $X = 5.1'$.

The maximum moment at this section is then, $M = -200{,}000(5.1-0.75) - 1100 \times \frac{5.1^2}{2} + 240{,}800 \times \frac{5.1^2}{6 \times 2} = -363{,}300'\#$ or $-4{,}360{,}000''\#$ with $b = 30''$, $d = \sqrt{\frac{4{,}360{,}000}{157 \times 30}} = 31''$ or total depth $= 35''$

The area of steel for moment $= A_s = \frac{4{,}360{,}000}{20{,}000 \times .866 \times 31} = 8.1\square''$ No. of rods for bond $= \frac{141{,}500}{4 \times 150 \times .866 \times 31} = 8.8\square''$. Therefore use 9-1"□ rods hooked each end in the top of the strap.

The maximum shear occurs at the inside face of the exterior column $V = -200{,}000 - 1100 \times 1.5 + 240{,}800/6 \times 1.5 = 141{,}500\#$. The critical width for shear in the plane of the longitudinal bars will include not only the width of the strap but also the extra width* of the exterior footing at this plane. With the proposed arrangement of the exterior footing, the shearing width in the plane of the longitudinal reinforcement is approximately $30 + 2 \times \frac{1}{8} \times 51 = 43''$ ∴ shear $= \frac{141{,}500}{43 \times 31 \times .866} = 122\#/\square''$ requiring stirrups which are figured in the same manner as for an ordinary beam. The unit shear at the inner edge of the exterior footing is considerably less than 60#/□".

The average soil pressure under the exterior footing inclusive of the weight of the strap is $\frac{240{,}800 + 21{,}000\text{ (wt. of footing)}}{11.0 \times 6.0} = 3970\#/\square'$ which is less than 4,000#/□' allowable.

Next consider the exterior footing design. The net upward pressure on each of the cantilever portions of the footing is $\frac{240{,}800}{11 \times 6} = 3650$ lbs. per sq. ft.

The maximum moment in the cantilever at the edge of the strap is =

$3650 \times 6 \times 4.25 \times \frac{4.25}{2} \times 12 = 2{,}370{,}000''\#$ Then $A_s = \frac{2{,}370{,}000}{20{,}000 \times .866 \times 31} = 4.42\square'' = 15\text{-}\frac{5}{8}''\phi$ Hkd. ea. end.

For bond - no. of $\frac{5}{8}''\phi$ bars $= \frac{3650 \times 4.25 \times 6}{1.96 \times 150 \times 31 \times .866} = 12$ ∴ use 15-5/8"φ Hooked each end.

* 1/8 of overhang.

† Adapted from Urquhart & O'Rourke, Design of Conc. Structures, McGraw-Hill.

STRUCTURAL - FOUNDATIONS

PILE DATA

TABLE A - PILE SPACING AND LOADS.†

TYPE OF PILE	SPACING		LOADS	
	MIN. C TO C	REMARKS	USUAL LOAD	REMARKS
Wood	2'-0"	2'-6" Usual	15 Tons 6" Point 20 Tons 8" Point	
Composite	2'-6"	do.	Same as wood.	
Cast in place concrete.	2'-6"	Increase spacing 1" per ton for loads over 30 tons. Increase spacing to 3'-0" for lengths over 30'-0"	30 Tons	Increase 2 Tons for each increase in point diameter over 15" up to 40 Tons max. & depending on bearing strata.
Pre cast conc.	2'-6"	Varies with pile design.	30 Tons	Varies with design.
Concrete filled steel pipe driven Open ended	2'-0" Rock 2'-6" Hard Pan 2'-6" Boulders or gravel-boulder 2'-6" Friction	Dia. of tube plus 10" not less than 2'-0" " " " " 20" do. 2'-6" " " " " 20" " " " 2'-6" Same as cast in place.	49.5 to 168 Tons 34.7 to 70 Tons 30.0 to 50 Tons 30 Tons	See Pg. 2-62 do. do. Same as cast in place.
Steel H piles.	2'-0" Rock 2'-6" Friction	Also not less than two times maxim. dimension, depends also on bearing strata	40 to 65 Tons Max. 30 Tons	Depends on pile size. 40 tons refusal in hard pan or in gravel or boulders and when over 40'-0" long.
Drilled in Caissons.		Depend on load.	Up to 1500 Tons	Depend on size of pile, core & socket depth.

Load capacity for piles driven to resistance are usually computed with Eng. News-Record Formulas, see specifications. In case piles are driven into soft clays, silts or mud without reaching a hard stratum formula should be checked by load test.

TABLE B - PROBABLE PENETRATION EXPECTANCY FOR FRICTION PILES.*

MATERIAL	PENETRATION	REMARKS
Clean compact sand.	Slight	Usually jetted.
Other sands.	20 ft.	
Sandy clay.	30 ft.	
Pure clay.	35 ft.	
Clay and silt.	45 ft.	
Silt and mud.	50 to 100 ft.	
Glacial till.	Slight	Piles can not be driven.

*Penetration can be best determined by test piles or test rods. This table is to be used only for a rough indication from borings.

SAFE UPLIFT STRENGTH OF PILES.

Friction Piles - in sand, clay or gravel. Use one-half the safe bearing load.

Point Bearing Piles (Piles driven to hard stratum). Compute by contact surface area x shearing strength of material penetrated. See p. 4-74 for soil shearing values - Note: for sand 250 lb. per sq. ft. suggested.

Full size tests are desirable on account of the difficulty of establishing data for computation.

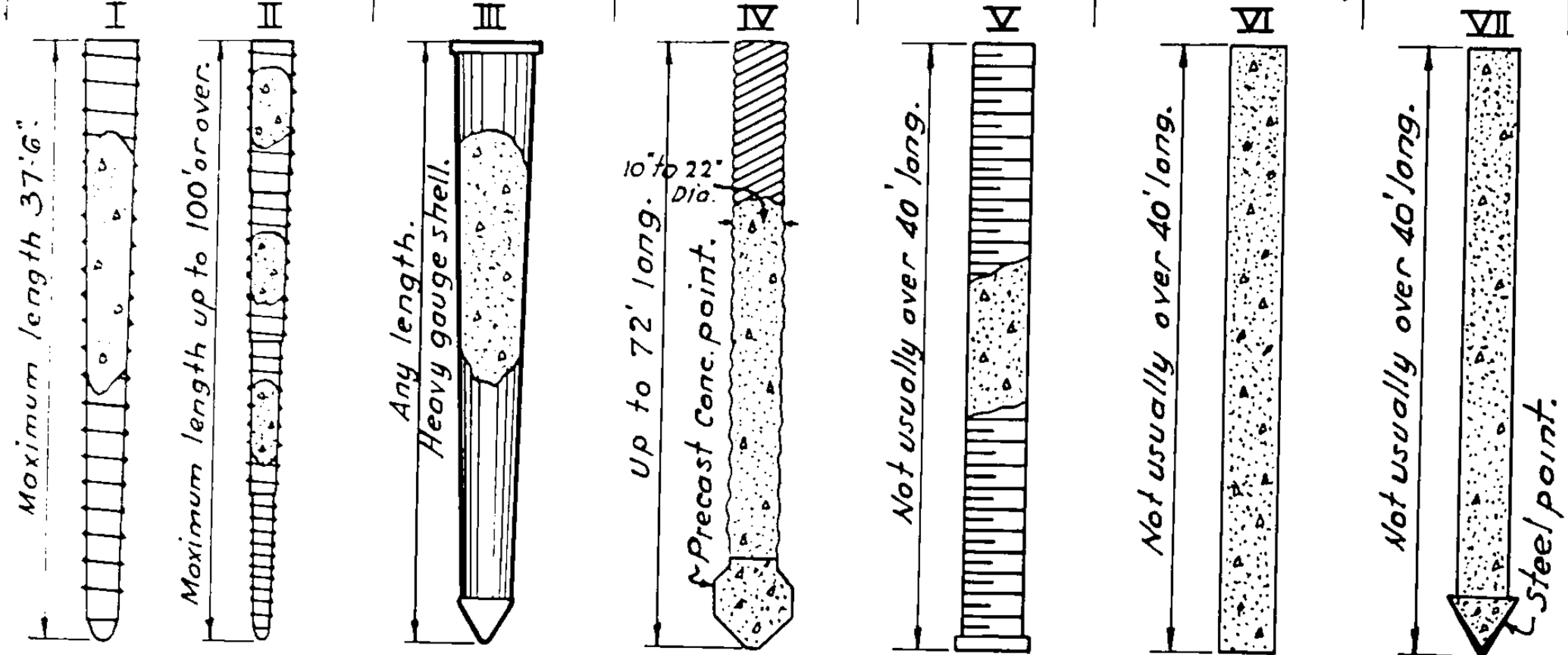
† Based on New York City Building Code.

STRUCTURAL — FOUNDATIONS

TYPES OF PILES.

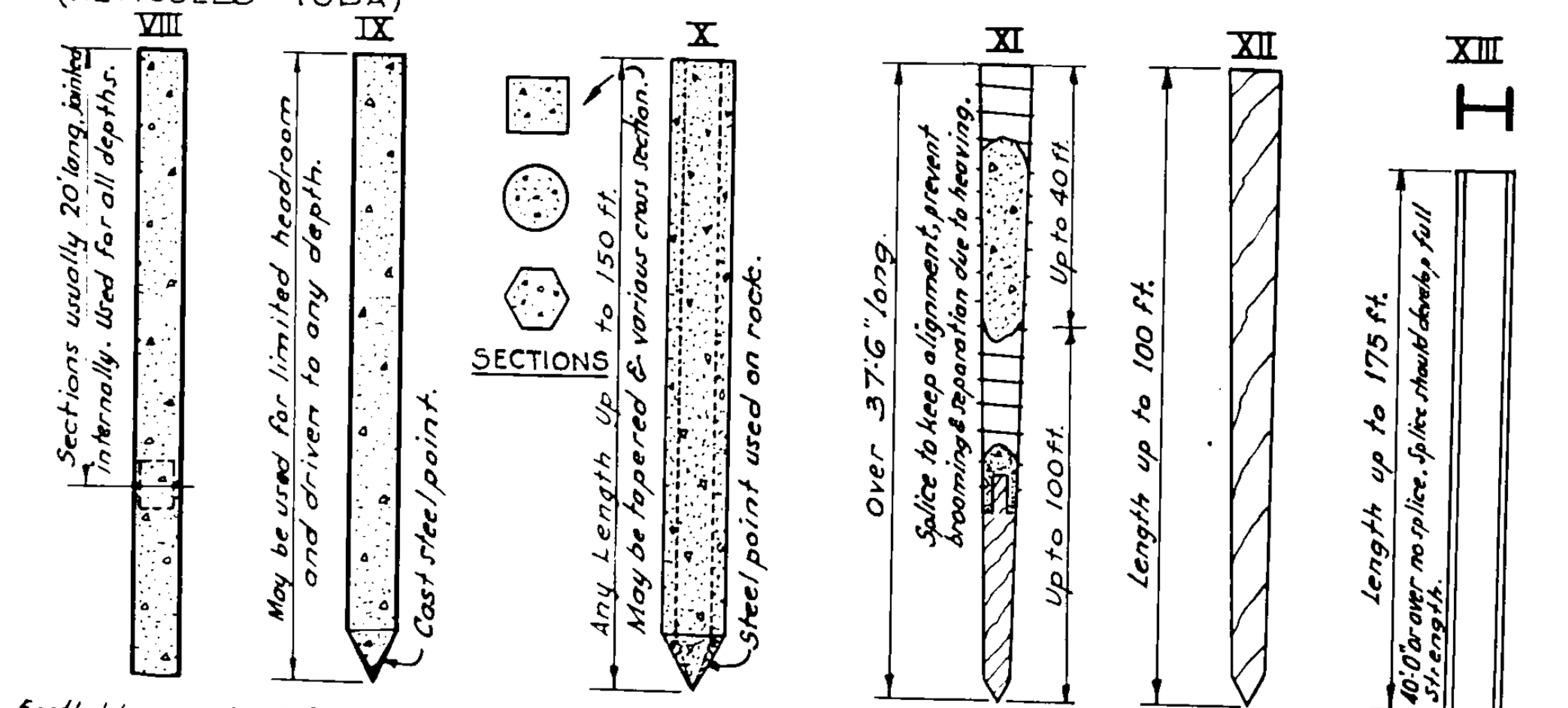
CAST-IN-PLACE PILES.

TAPERED PILES STANDARD - STEP (RAYMOND)	TAPERED FLUTED PILE (UNION)	BUTTON BOTTOM PILE (WESTERN)	CASED CONCR. PILE (MAC. ARTHUR)	UNCASED STRAIGHT SHAFT (MAC. ARTHUR & WESTERN)	SIMPLEX PILE
I II	III	IV	V	VI	VII



Shell with inserted mandril driven to resistance. Core withdrawn, casing filled with concrete.	Shell with point driven to resistance and filled with Concrete.	Driven to resistance with steel pipe casing & point. Permanent casing inserted, filled with Concrete & driving casing withdrawn.	Driven to resistance with steel pipe casing & Core. Core removed. Permanent casing inserted, filled with concr. & driving casing withdrawn.	Driven to resistance with steel pipe casing & core. Core removed. Casing filled with concrete and then withdrawn.	Driven to resistance with steel pipe casing & point. Casing filled with concrete & then withdrawn.

STEEL PIPE PILES (HERCULES - TUBA) OPEN END	POINT	PRECAST PILE	COMPOSITE PILE	WOOD PILE	H SECTION STEEL PILE
VIII	IX	X	XI	XII	XIII



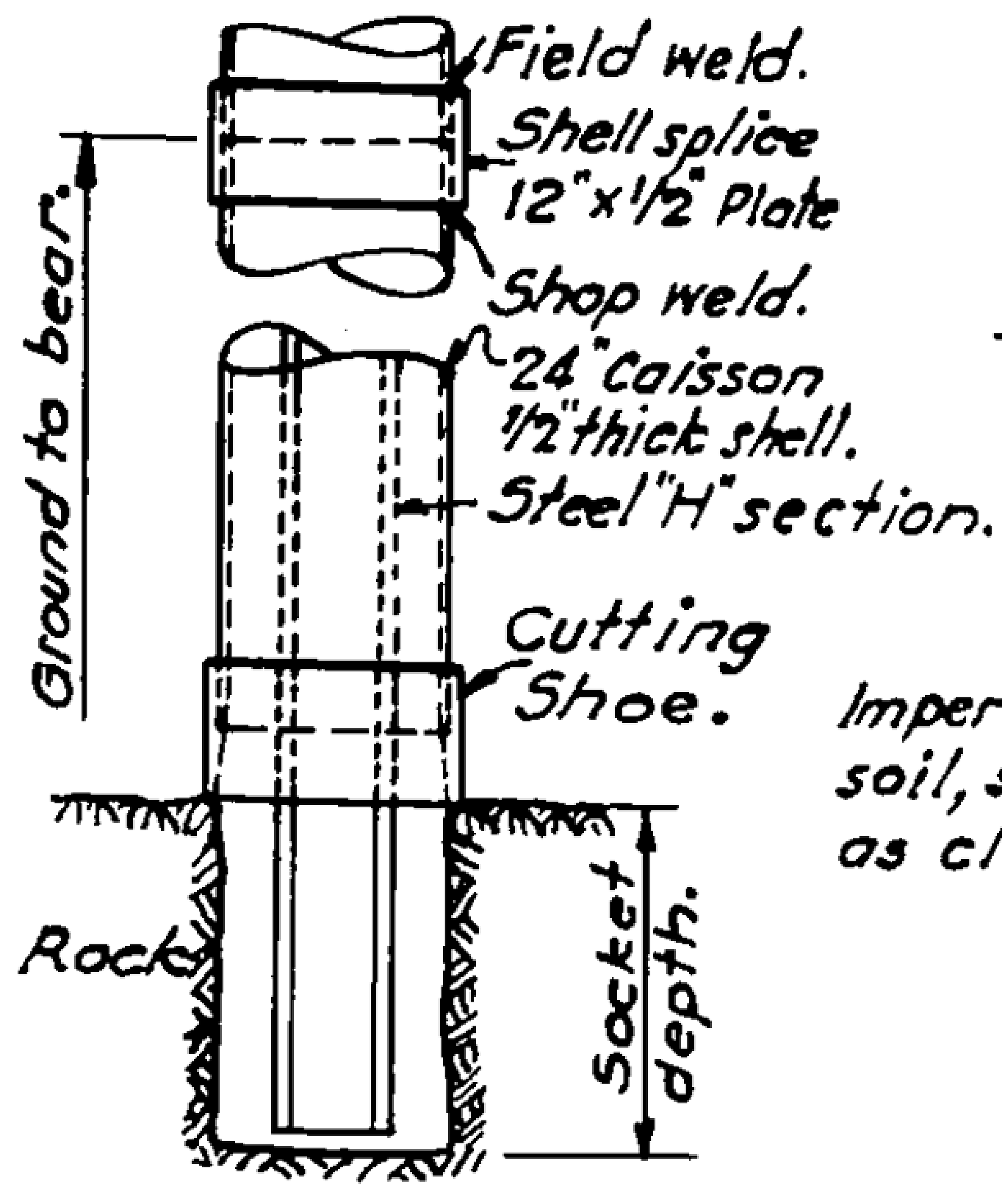
Earth blown out with air jet as driven to refusal and loaded as column.	Driven to refusal or to resistance.	Driven to refusal or to resistance.	Wood pile driven below water level & to resistance. Upper section spliced to wood pile & filled with concrete.	Driven to resistance.	Driven to refusal or resistance. Used where penetration is in hard material.

For general notes see Pg. 2·61.

STRUCTURAL – FOUNDATIONS

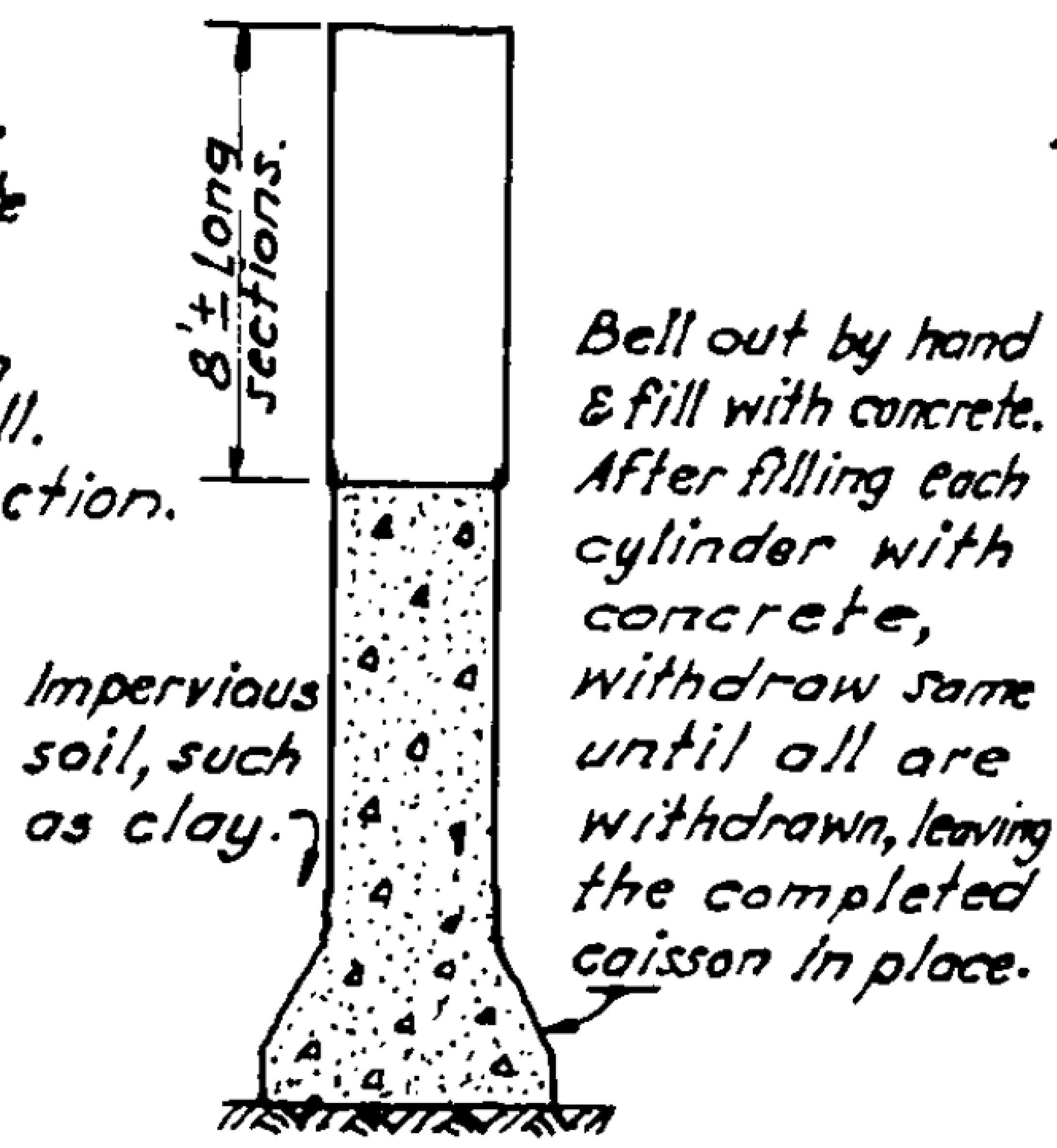
TYPES OF PILES.

DRILLED IN CAISSON. (WESTERN ; SPENCER, WHITE & PRENTIS).



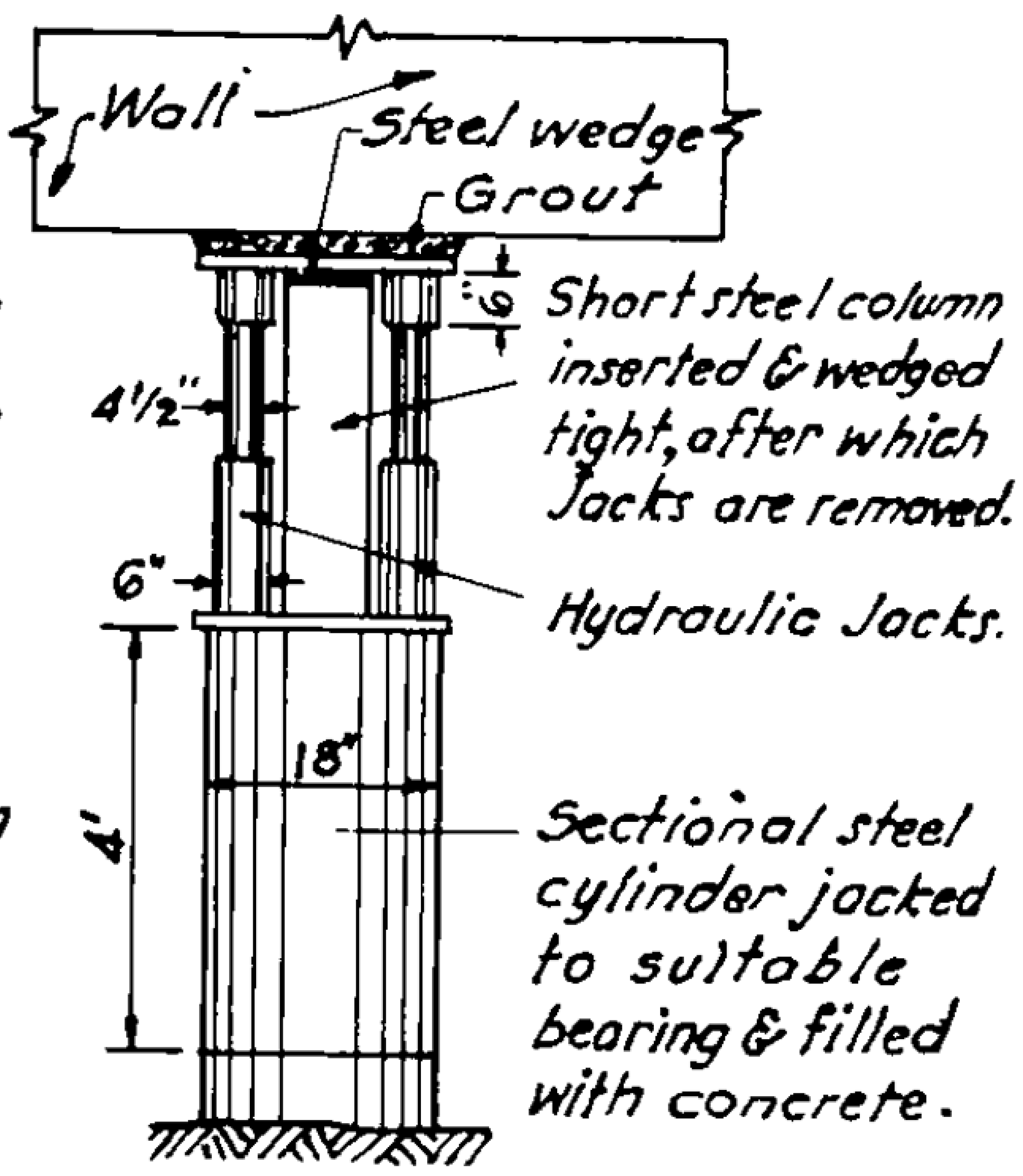
Shell driven to rock, cleaned out. Rock socket is drilled, core inserted & shell filled with concrete.

GOW CAISSON PILE.



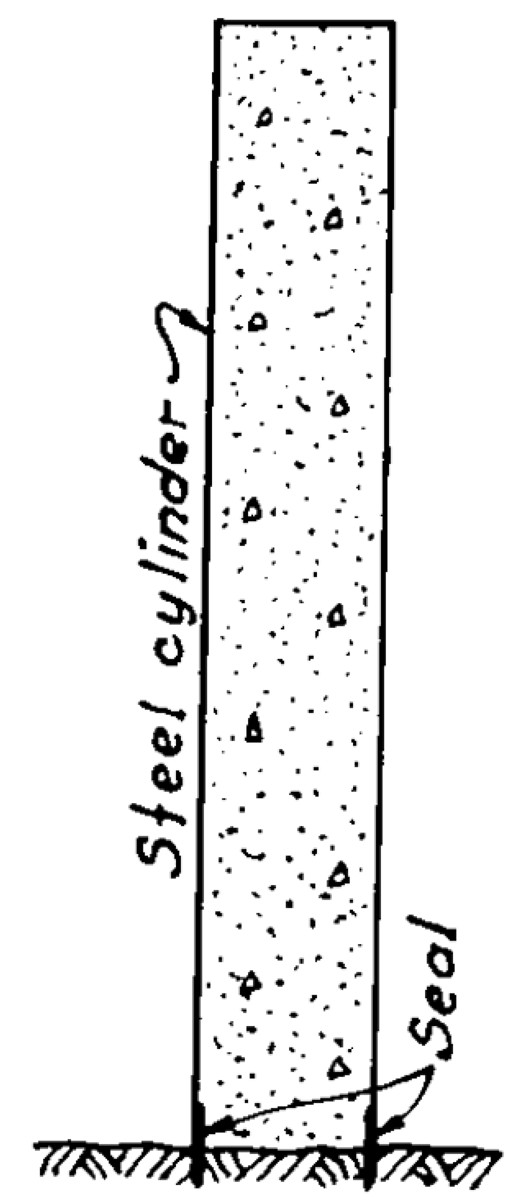
Excavate shallow pit by hand & place top cylinder in pit. Second cylinder is placed inside the first & repeat process until caisson reaches its full depth.

PIPE PILE UNDERPINNING (HERCULES – PRETEST)



Cylinder is tested with jacks to an overload capacity.

WET CAISSON.



Steel cylinder sunk to rock as earth is removed. Bottom sealed, water removed and filled with concrete.

PILE NO.*	NOTES
I, II, III, V, XI	Precautions are required to prevent collapsing of shell when driving adjoining piles.
VI, VII	With uncased piles, precautions should be taken to prevent damage due to driving adjoining piles because pile has no sheet casing around it.
IV, V	When shell is inserted inside driving casing and casing withdrawn, soil must be relied upon to grip pile as firmly as if it had been driven without casing.
VIII	Concrete steel pipe piles sometimes driven open ended to predetermined depth and filled with concrete. After concrete has set pile is driven to required resistance. This is done so as not to disturb adjoining wall and foundation and also when driving cast-in-place piles to prevent heaving.
X	Precast piles are used for marine structure, require heavy handling equipment.
XI, XII	Cut off wood pile below permanent water level. Creosoted wood piles used with cut off above permanent water level for limited life. Precautions against overdriving should be taken. Vulnerable to marine borers.
I TO IX	The piles have less give under hammer than a pile of more flexible material such as wood or concrete and consequently if driven to the same resistance, have a greater safety factor.
XIII	Steel H sections should not be used through cinders, ash fill or normally active rust producing material without adequate protection.
CAISSONS	These are usually used when sinking foundation to considerable depths with heavy loads. This is done bu wood sheeting, steel sheeting and steel cylinders. In case of water condition, operations carried on under Compressed air.

* For sketch see Pg. 2-60

STRUCTURAL - FOUNDATIONS

CONCRETE FILLED STEEL PIPE PILES DRIVEN TO REFUSAL.

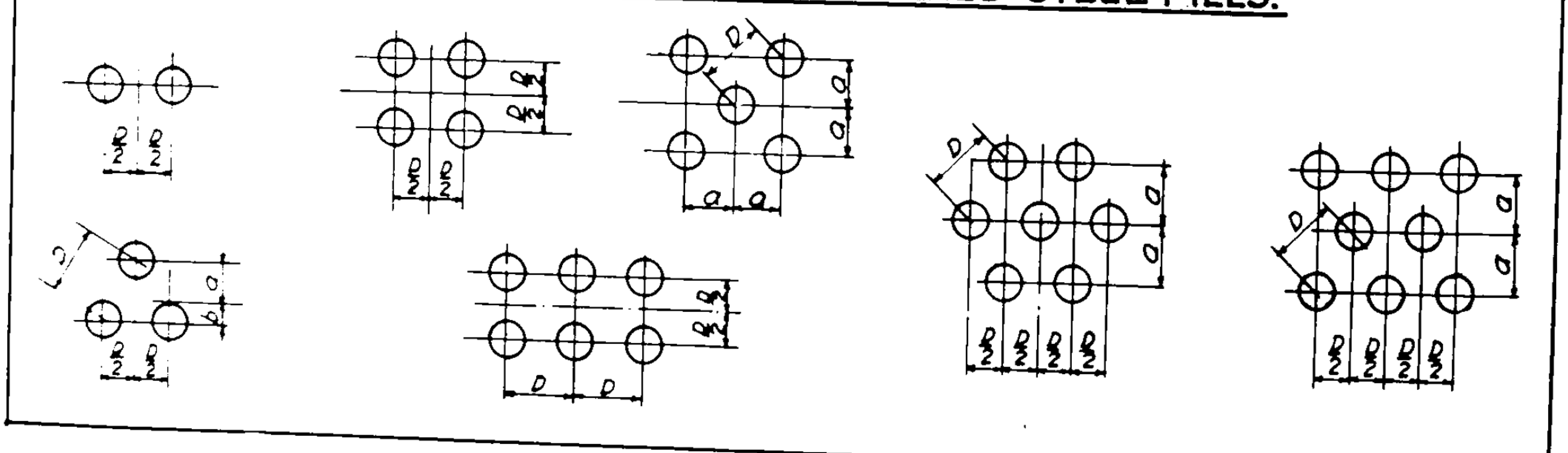
ALLOWABLE LOAD IN TONS AND SPACING.

DIAMETER	WALL THICKNESS.	ON ROCK LESS THAN 60'	ON ROCK MORE THAN 60'	ON ROCK SPACING C. To C.	ON HARD PAN LESS THAN 60'	ON HARD PAN MORE THAN 60'	ON HARD PAN SPACING C. To C.	ON BOULDERS OR GRAVEL & BOULDERS. LESS THAN 60'	ON BOULDERS OR GRAVEL & BOULDERS. MORE THAN 60'	ON BOULDERS OR GRAVEL & BOULDERS. SPACING C. To C.
10¾"	5/16"	49.5		24"	34.7		30"	30.0		30"
	3/8"	55.0		24"	38.5		30"	30.0		30"
	7/16"	60.5		24"	42.4		30"	30.3		30"
	1/2"	66.0		24"	46.2		30"	33.0		30"
12¾"	5/16"	63.0		24"	44.1		30"	31.5		32"
	3/8"	70.0		24"	49.0		30"	35.0		32"
	7/16"	77.0		24"	53.9		30"	38.5		32"
	1/2"	84.0		24"	58.8		30"	42.0		32"
14"	3/8"	80.0		24"	56.0		30"	40.0		34"
	7/16"	88.0		24"	61.6		30"	44.0		34"
	1/2"	96.0		24"	67.2		30"	48.0		34"
15"	3/8"	90.0		25"	63.0		30"	45.0		35"
	7/16"	99.0		25"	69.3		30"	49.5		35"
	1/2"	108.0		25"	70.0		30"	50.0		35"
16"	3/8"	100.0		26"	70.0		30"	50.0		36"
	7/16"	110.0		26"	70.0		30"	50.0		36"
	1/2"	120.0		26"	70.0		30"	50.0		36"
18"	3/8"	120.0		28"	70.0		30"	50.0		38"
	7/16"	132.0		28"	70.0		30"	50.0		38"
	1/2"	144.0	132.0	28"	70.0	70.0	30"	50.0	50.0	38"
	5/8"	144.0	132.0	28"	70.0	70.0	30"	50.0	50.0	38"
20"	3/8"	140.0		30"	70.0		30"	50.0		40"
	7/16"	154.0		30"	70.0		30"	50.0		40"
	1/2"	168.0	154.0	30"	70.0	70.0	30"	50.0	50.0	40"
	5/8"	168.0	154.0	30"	70.0	70.0	30"	50.0	50.0	40"

GROUP PILE SPACING.

CENTER TO CENTER OF PILES "D" INCHES	3-PILE PIERS a INCHES	3-PILE PIERS b INCHES	5-PILE PIERS a INCHES	7 or 8-PILE PIERS a INCHES
24	14	7	17	21
25	15	7½	18	22
26	15	7½	18½	22½
28	16	8	20	24½
30	17	8½	21½	26
32	19	9½	22½	28
34	20	10	24	29½
35	20	10	25	30½
36	21	10½	25½	31
38	22	11	27	33
40	23	11½	28½	35
42	24	12	30	36½
44	25½	13	31½	38½

SPACING FOR CONCRETE FILLED STEEL PILES.



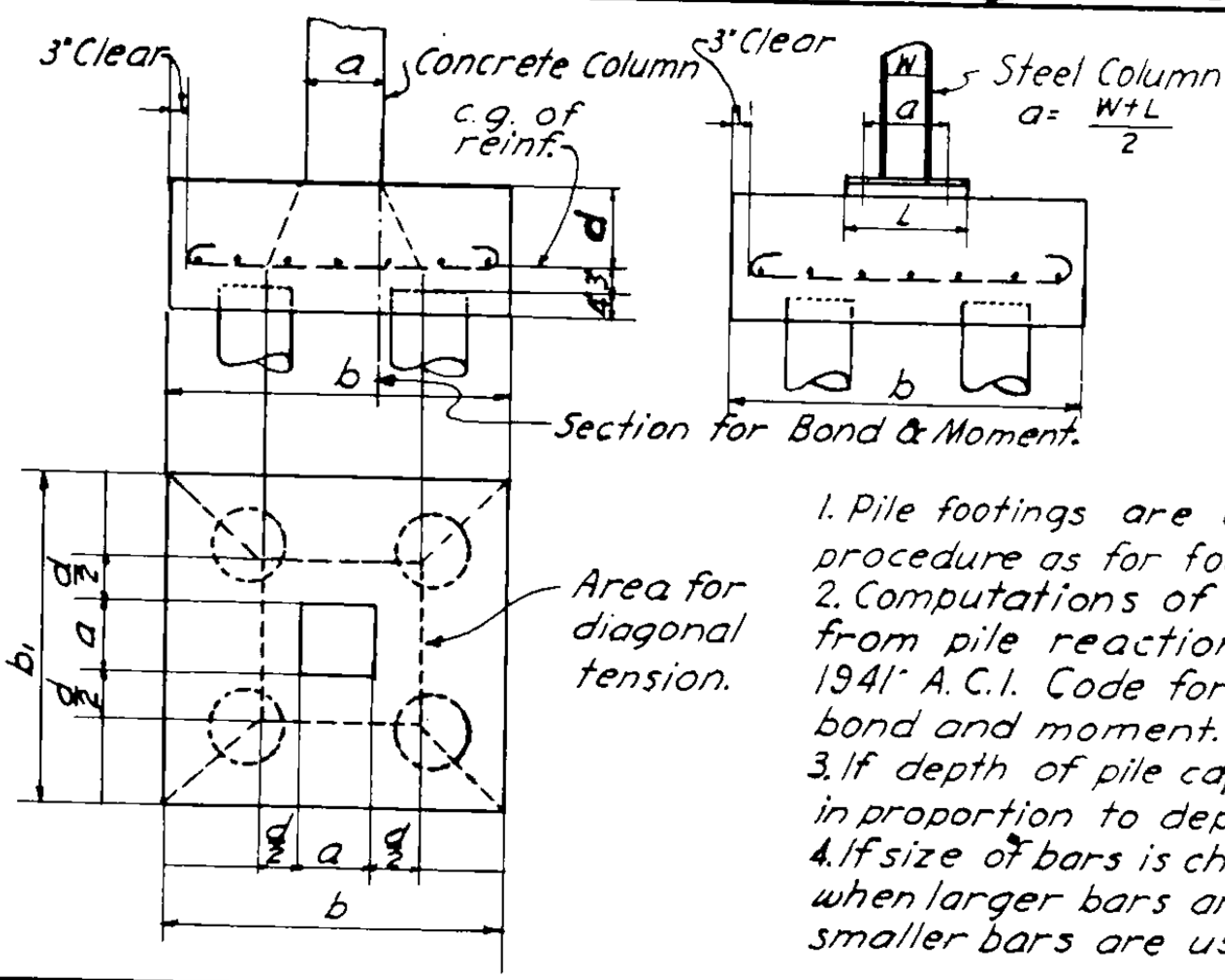
NOTE:

The above data meet the requirements of the New York City Building Code. The pile load is based on unit load of 500#/□" on the concrete and 7,500#/□" on the steel shell, the outside 1/16" being discounted for corrosion with values slightly modified so as to give figures more convenient for use.

Data based on pipes driven open, cleaned out and filled with concrete. Capacity of steel pipe driven closed same as for precast concrete piles, See Table A pg. 2-59.

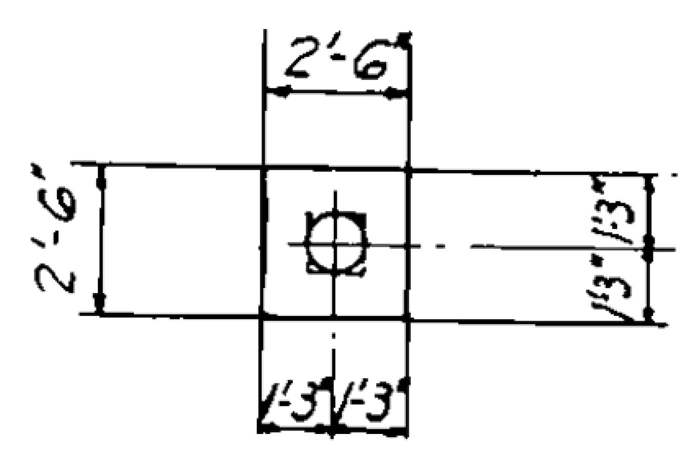
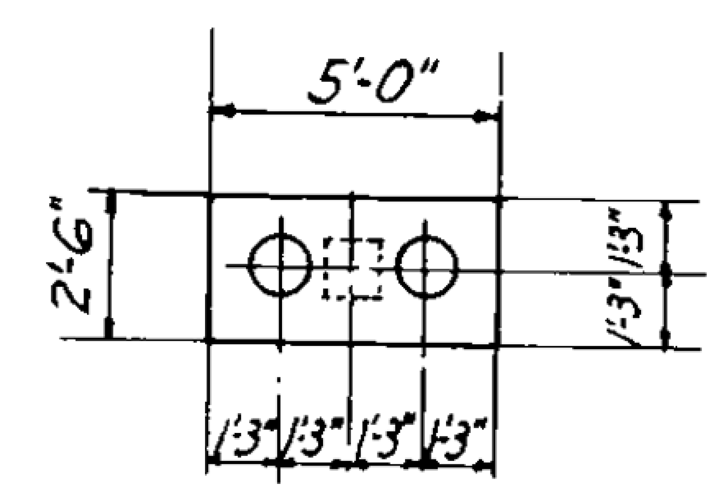
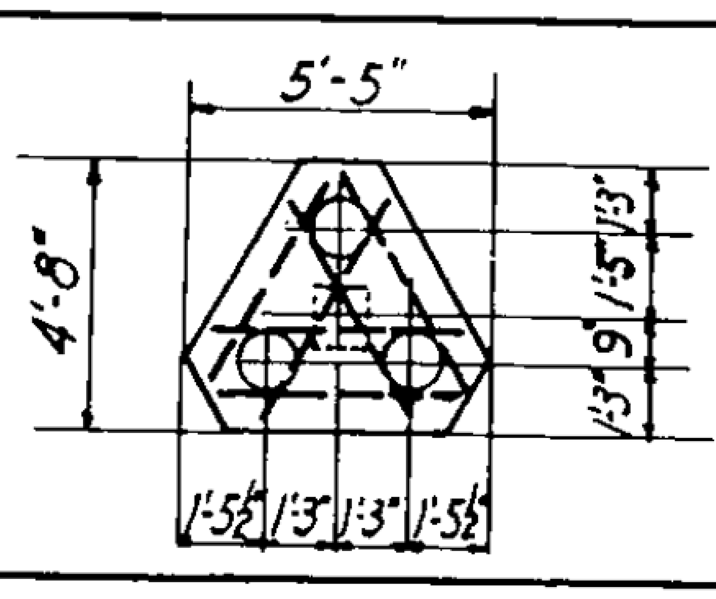
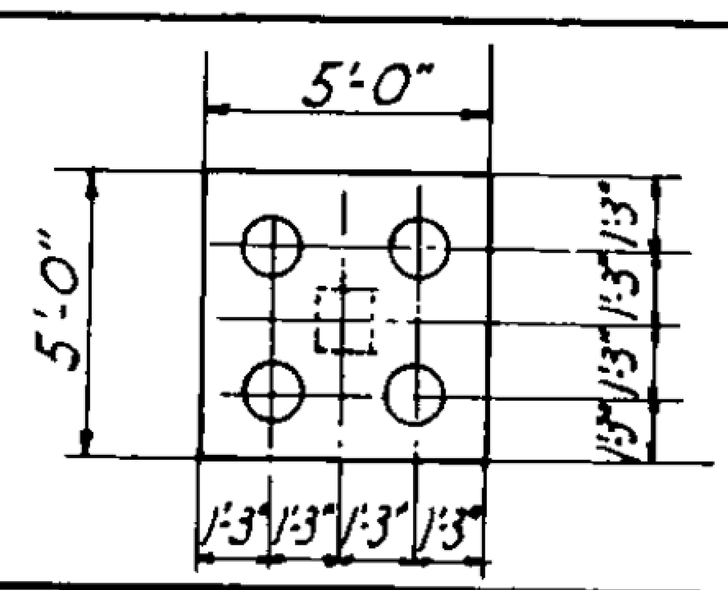
STRUCTURAL - FOUNDATIONS

PILE FOOTINGS.*



DESIGN DATA.		
f'_c = 2,000#/□"	f'_c = 3,000#/□"	f'_c = 3,750#/□"
f_c = 900#/□"	f_c = 1,350#/□"	f_c = 1,688#/□"
f_s = 20,000#/□"	f_s = 20,000#/□"	f_s = 20,000#/□"
v = 60#/□"	v = 75#/□"	v = 75#/□"
u = 112.5#/□"	u = 168#/□"	u = 200#/□"

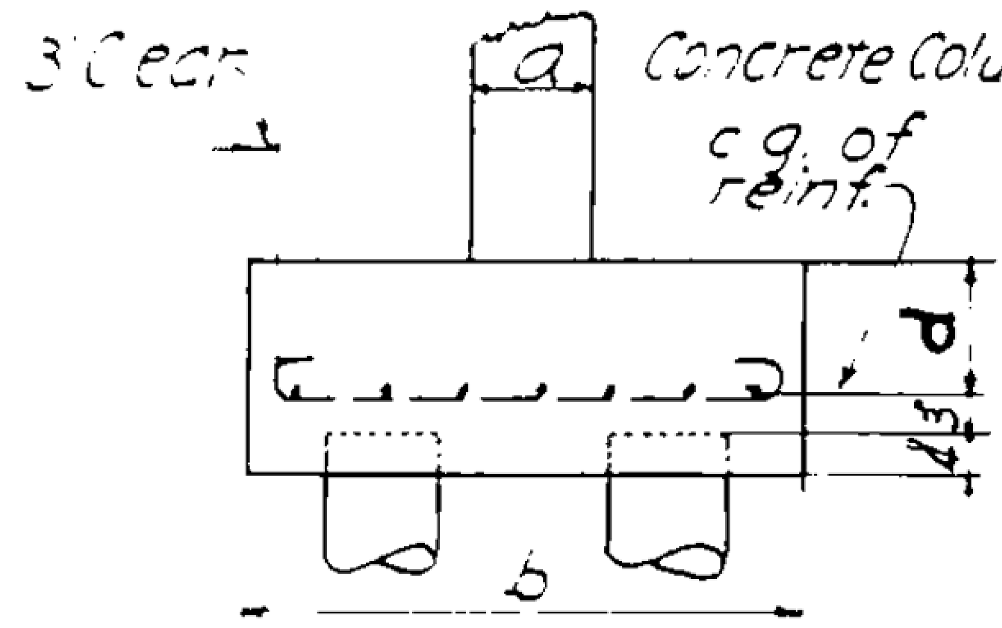
1. Pile footings are designed according to the same procedure as for footings on soil.
2. Computations of external shear at any section from pile reactions has been made according to 1941 A.C.I. Code for determining diagonal tension bond and moment.
3. If depth of pile caps is increased, decrease steel perimeter in proportion to depth.
4. If size of bars is changed:- Provide equivalent perimeter when larger bars are used; and equivalent area when smaller bars are used.

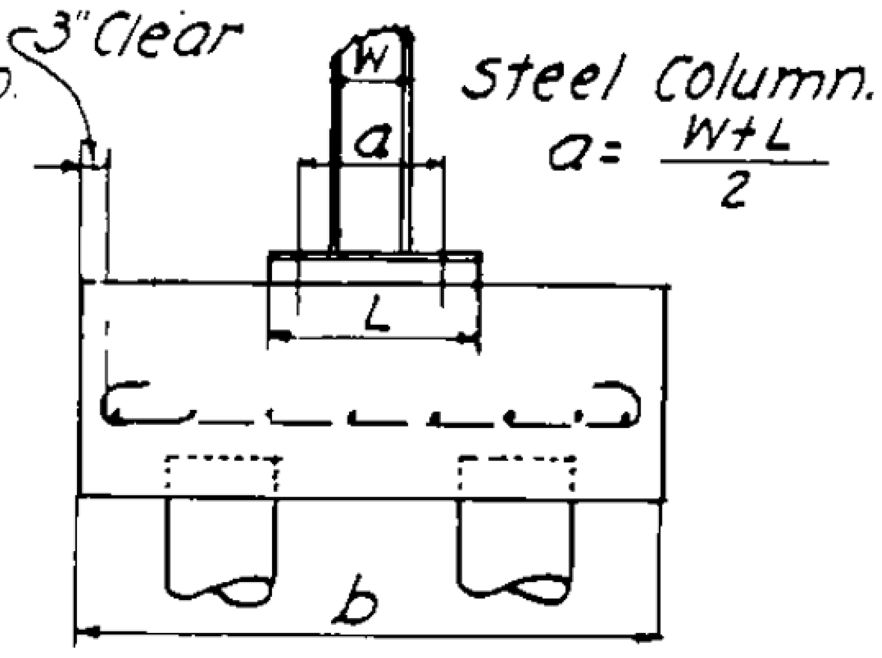
NUMBER OF PILES	PLAN	FOR ALL FOOTINGS			f'_c = 2,000#/□"			f'_c = 3,000#/□"			f'_c = 3,750#/□"		
		PILE VALUE IN KIPS	COLUMN LOAD IN KIPS	d (IN.)	a (IN.)	REINFORCEMENT LONG WAY	REINFORCEMENT SHORT WAY	a (IN.)	REINFORCEMENT LONG WAY	REINFORCEMENT SHORT WAY	a (IN.)	REINFORCEMENT LONG WAY	REINFORCEMENT SHORT WAY
1		20	18.5	12	–	3-5/8"φ	3-5/8"φ	–	3-5/8"φ	3-5/8"φ	–	3-5/8"φ	3-5/8"φ
		30	28.5	12	–	3-5/8"φ	3-5/8"φ	–	3-5/8"φ	3-5/8"φ	–	3-5/8"φ	3-5/8"φ
		40	38.5	12	–	3-5/8"φ	3-5/8"φ	–	3-5/8"φ	3-5/8"φ	–	3-5/8"φ	3-5/8"φ
		50	48.5	12	–	3-5/8"φ	3-5/8"φ	–	3-5/8"φ	3-5/8"φ	–	3-5/8"φ	3-5/8"φ
		60	58.5	12	–	3-5/8"φ	3-5/8"φ	–	3-5/8"φ	3-5/8"φ	–	3-5/8"φ	3-5/8"φ
2		20	37	12	7	6-5/8"φ	4-5/8"φ	7	4-5/8"φ	4-5/8"φ	7	4-5/8"φ	4-5/8"φ
		30	57	15	7	8-5/8"φ	4-5/8"φ	7	5-5/8"φ	4-5/8"φ	7	5-5/8"φ	4-5/8"φ
		40	76	17	9	9-5/8"φ	4-5/8"φ	9	6-5/8"φ	4-5/8"φ	9	5-5/8"φ	4-5/8"φ
		50	96	19	9	8-3/4"φ	4-5/8"φ	9	7-5/8"φ	4-5/8"φ	9	6-5/8"φ	4-5/8"φ
		60	116	20	10	8-7/8"φ	4-5/8"φ	9	8-5/8"φ	4-5/8"φ	9	7-5/8"φ	4-5/8"φ
3		20	54	15	8	3 Bands of 4-5/8"φ		7	3 Bands of 3-5/8"φ		7	3 Bands of 3-5/8"φ	
		30	83	17	9	" " " 5-5/8"φ		9	" " " 4-5/8"φ		9	" " " 3-5/8"φ	
		40	113	19	10	" " " 6-5/8"φ		9	" " " 4-5/8"φ		9	" " " 4-5/8"φ	
		50	143	20	11	" " " 8-5/8"φ		10	" " " 5-5/8"φ		9	" " " 4-5/8"φ	
		60	172	21	12	" " " 7-3/4"φ		10	" " " 6-5/8"φ		10	" " " 5-5/8"φ	
4		20	72	14	8	14-1/2"φ	14-1/2"φ	8	10-1/2"φ	10-1/2"φ	8	8-1/2"φ	8-1/2"φ
		30	112	15	10	17-5/8"φ	17-5/8"φ	9	14-1/2"φ	14-1/2"φ	9	12-1/2"φ	12-1/2"φ
		40	152	16	12	15-7/8"φ	15-7/8"φ	10	14-5/8"φ	14-5/8"φ	9	15-1/2"φ	15-1/2"φ
		50	192	17	12	16-1"φ	16-1"φ	11	17-5/8"φ	17-5/8"φ	10	14-5/8"φ	14-5/8"φ
		60	232	18	13	14-1"□	14-1"□	12	16-3/4"φ	16-3/4"φ	12	16-5/8"φ	16-5/8"φ

*Based on A.C.I. Code - 1941.

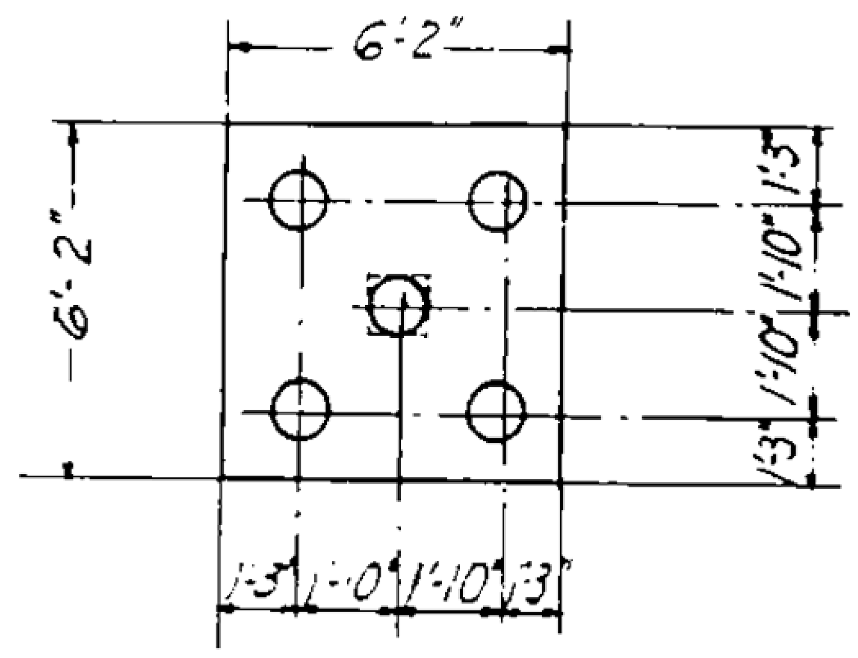
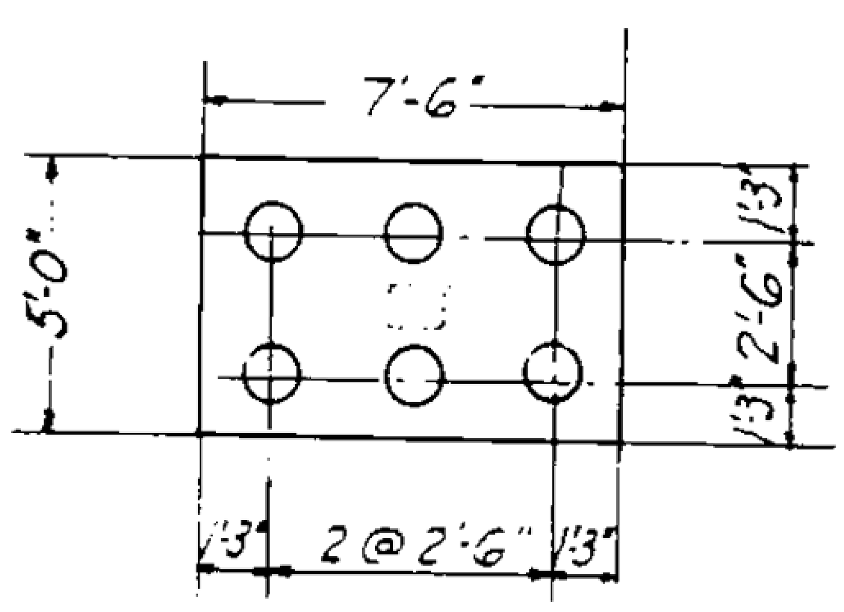
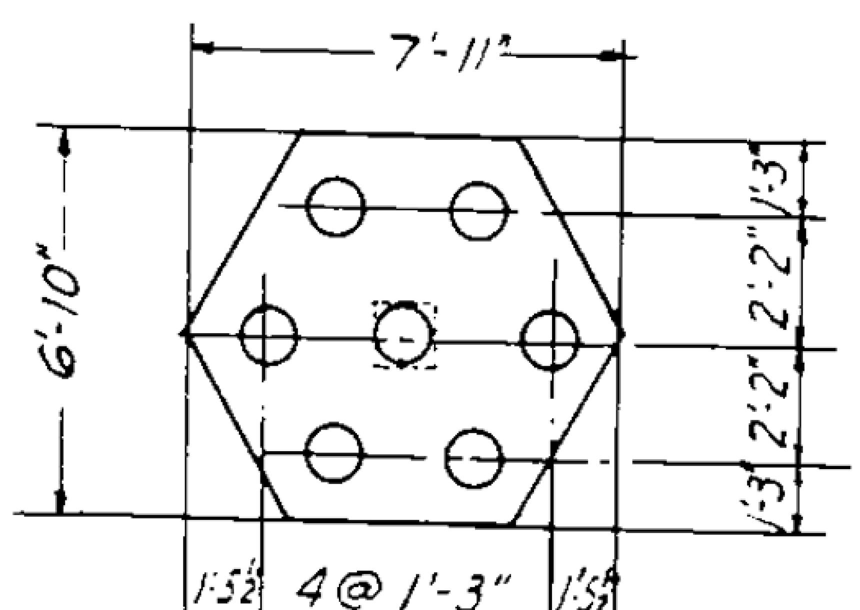
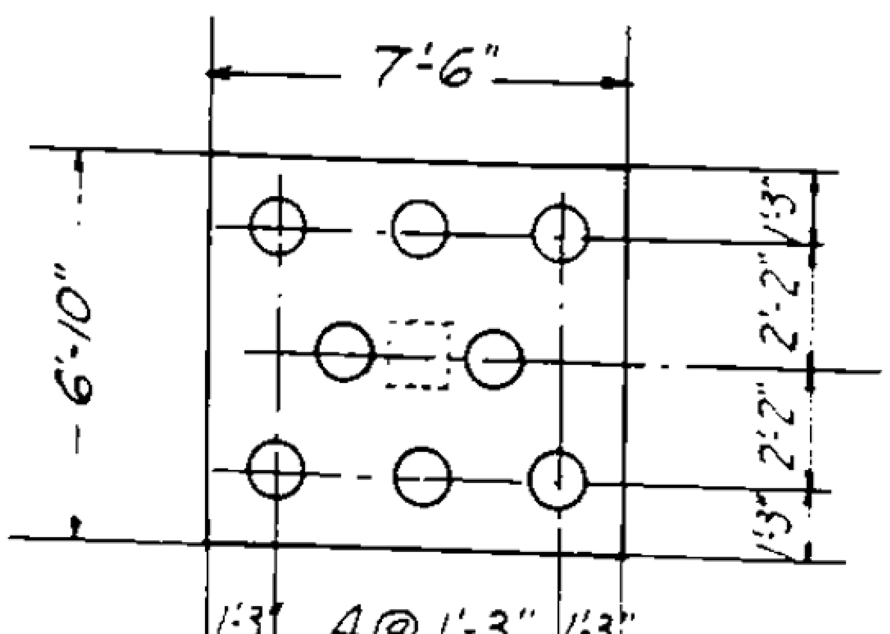
STRUCTURAL - FOUNDATIONS

PILE FOOTINGS.*





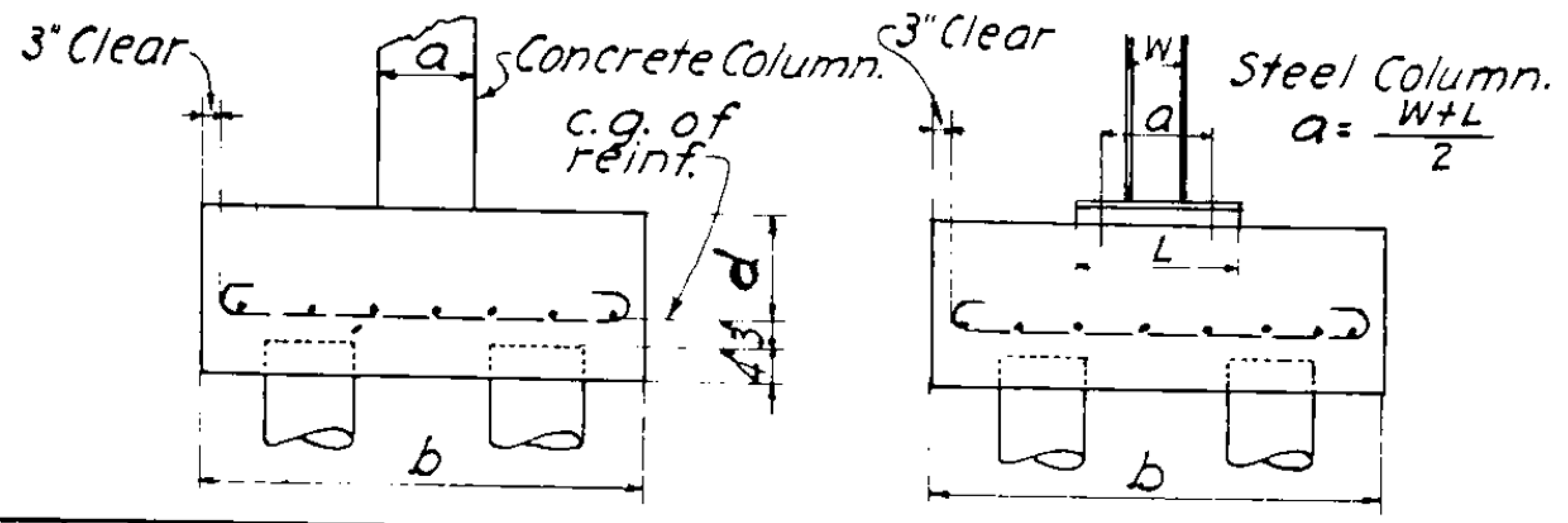
DESIGN DATA.		
f'_c = 2,000 #/□"	f'_c = 3,000 #/□"	f'_c = 3,750 #/□"
f_c = 900 #/□"	f_c = 1,350 #/□"	f_c = 1,688 #/□"
f_s = 20,000 #/□"	f_s = 20,000 #/□"	f_s = 20,000 #/□"
v = 60 #/□"	v = 75 #/□"	v = 75 #/□"
u = 112.5 #/□"	u = 168 #/□"	u = 200 #/□"

Number of Piles	Plan	For All Footings: Pile Value in Kips	For All Footings: Column Load in Kips	d (in.)	f'_c = 2,000 #/□": a (in.)	f'_c = 2,000 #/□": Reinforcement Long Way	f'_c = 2,000 #/□": Reinforcement Short Way	f'_c = 3,000 #/□": a (in.)	f'_c = 3,000 #/□": Reinforcement Long Way	f'_c = 3,000 #/□": Reinforcement Short Way	f'_c = 3,750 #/□": a (in.)	f'_c = 3,750 #/□": Reinforcement Long Way	f'_c = 3,750 #/□": Reinforcement Short Way
5		20	90	15	10	13-½"φ	13-½"φ	9	7-⅝"φ	7-⅝"φ	9	8-½"φ	8-½"φ
		30	137	18	11	17-½"φ	17-½"φ	10	12-½"φ	12-½"φ	10	12-½"φ	12-½"φ
		40	186	21	13	20-½"φ	20-½"φ	11	14-½"φ	14-½"φ	10	14-½"φ	14-½"φ
		50	235	22	13	19-⅝"φ	19-⅝"φ	12	13-⅝"φ	13-⅝"φ	11	11-⅝"φ	11-⅝"φ
		60	284	24	14	18-¾"φ	18-¾"φ	14	14-⅝"φ	14-⅝"φ	12	12-⅝"φ	12-⅝"φ
6		20	106	22	10	10-½"φ	14-½"φ	9	7-⅝"φ	9-½"φ	8	7-⅝"φ	8-½"φ
		30	164	27	12	12-½"φ	17-½"φ	10	8-⅝"φ	11-½"φ	10	6-¾"φ	10-½"φ
		40	222	32	14	13-½"φ	19-½"φ	12	9-⅝"φ	13-½"φ	11	7-¾"φ	11-½"φ
		50	280	35	14	15-½"φ	22-½"φ	13	7-¾"φ	15-½"φ	13	7-¾"φ	13-½"φ
		60	338	36	16	17-½"φ	26-½"φ	15	8-¾"φ	18-½"φ	14	8-¾"φ	15-½"φ
7		20	122	21	11	14-½"φ	9-½"φ	10	9-½"φ	9-½"φ	9	10-½"φ	9-½"φ
		30	188	27	13	17-½"φ	11-½"φ	12	11-½"φ	10-½"φ	11	11-½"φ	10-½"φ
		40	255	29	14	17-⅝"φ	11-⅝"φ	14	14-½"φ	12-½"φ	13	13-½"φ	12-½"φ
		50	325	31	15	20-⅝"φ	13-⅝"φ	15	17-½"φ	14-½"φ	14	15-½"φ	14-½"φ
		60	393	32	16	23-⅝"φ	16-⅝"φ	16	20-½"φ	15-½"φ	15	16-½"φ	16-½"φ
8		20	142	21	11	13-½"φ	13-½"φ	10	9-⅝"φ	9-⅝"φ	9	6-¾"φ	6-¾"φ
		30	220	24	13	20-½"φ	20-½"φ	12	11-⅝"φ	11-⅝"φ	11	8-¾"φ	8-¾"φ
		40	298	27	14	23-½"φ	23-½"φ	13	13-⅝"φ	13-⅝"φ	12	10-¾"	10-¾"φ
		50	375	30	16	21-⅝"φ	21-⅝"φ	15	14-⅝"φ	14-⅝"φ	14	10-¾"φ	10-¾"φ
		60	454	32	18	24-⅝"φ	24-⅝"φ	17	16-⅝"φ	16-⅝"φ	16	11-¾"φ	11-¾"φ.

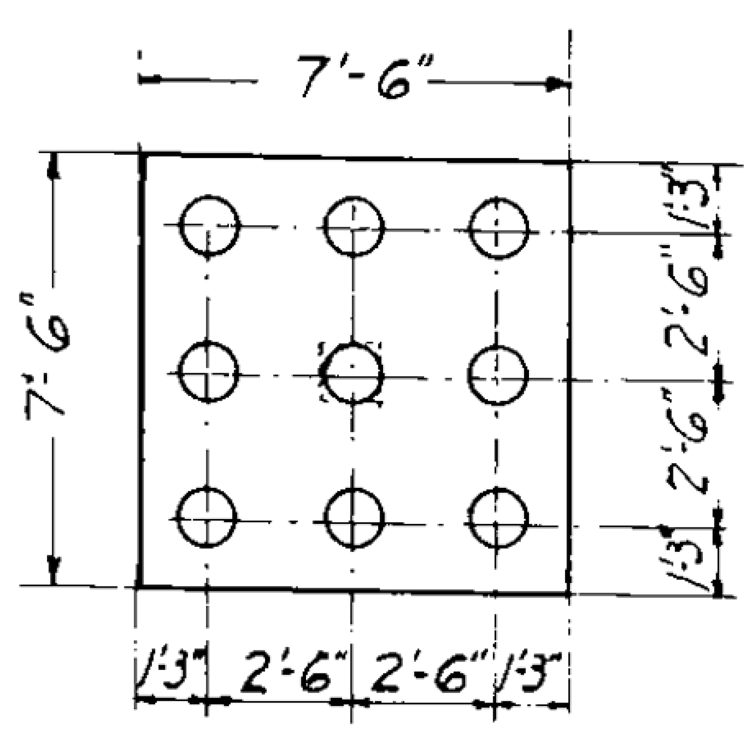
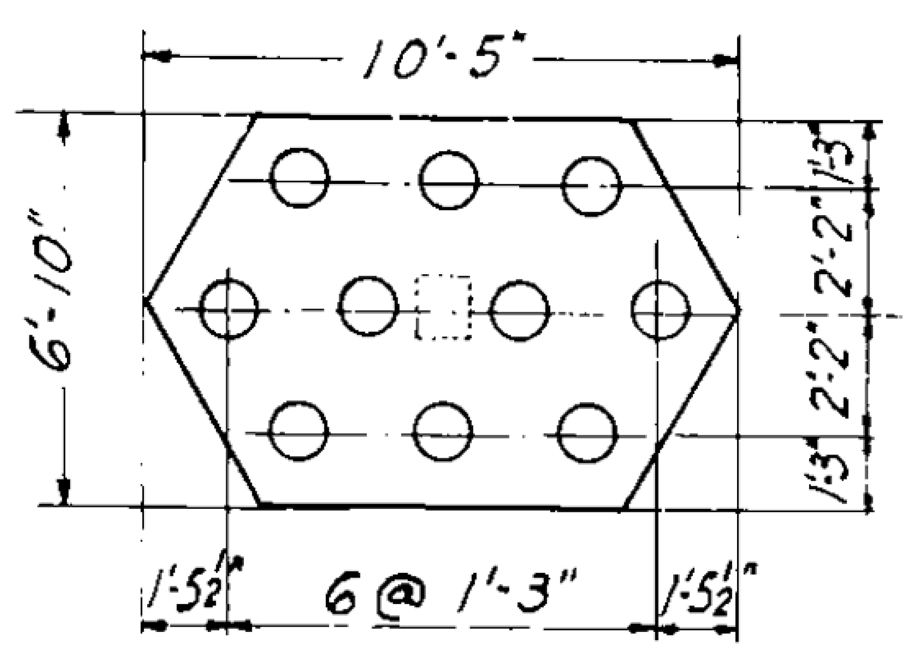
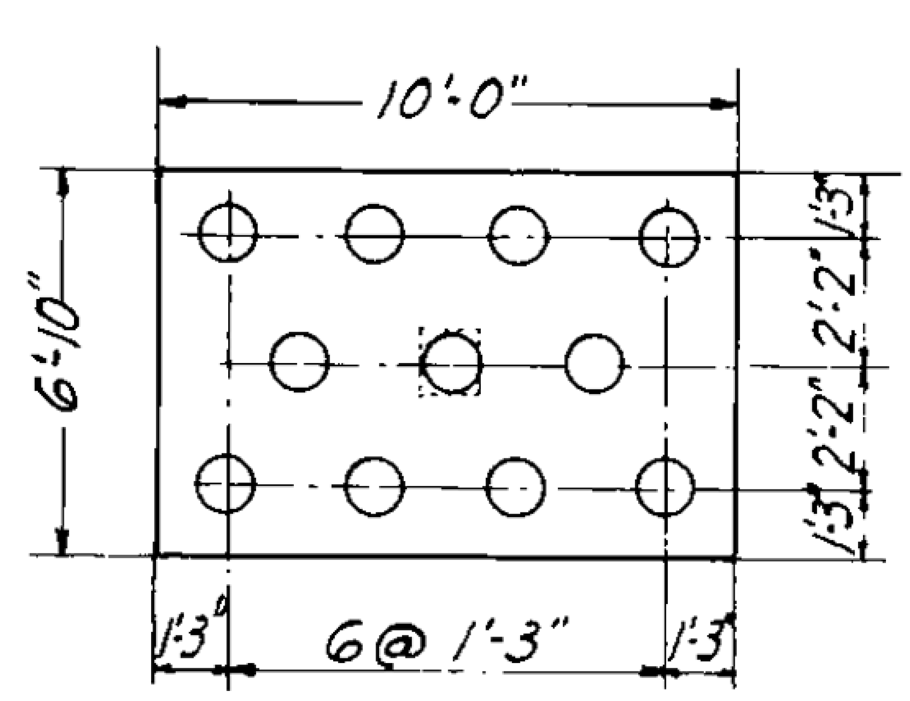
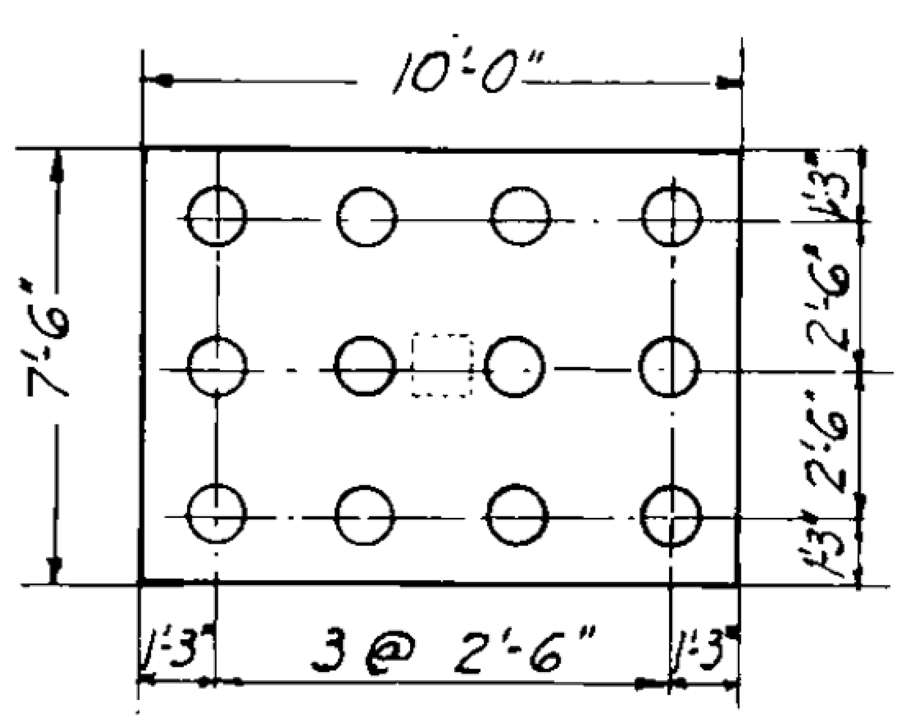
* Based on A.C.I. Code - 1941.

STRUCTURAL - FOUNDATIONS

PILE FOOTINGS.*



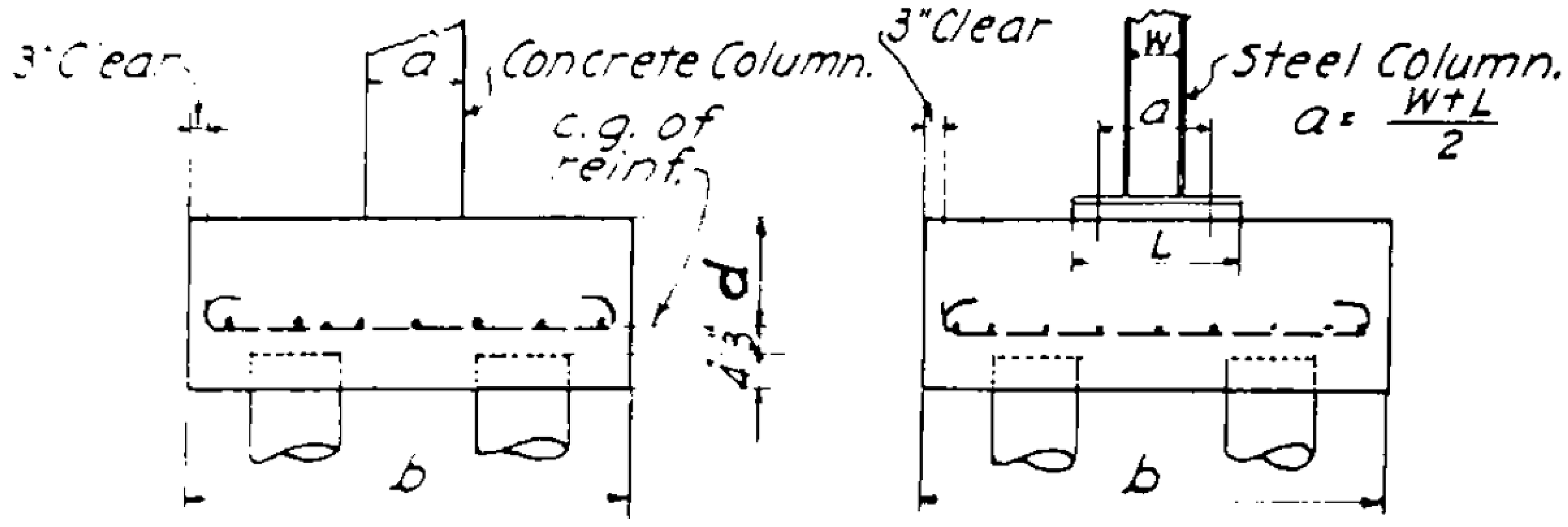
DESIGN DATA.		
f'_c = 2,000#/□"	f'_c = 3,000#/□"	f'_c = 3,750#/□"
f_c = 900#/□"	f_c = 1,350#/□"	f_c = 1,688#/□"
f_s = 20,000#/□"	f_s = 20,000#/□"	f_s = 20,000#/□"
v = 60#/□"	v = 75#/□"	v = 75#/□"
u = 112.5#/□"	u = 168#/□"	u = 200#/□"

Number of Piles	Plan	For All Footings			f'_c = 2,000#/□"			f'_c = 3,000#/□"			f'_c = 3,750#/□"		
		Pile Value in Kips	Column Load in Kips	d (in.)	a (in.)	Reinforcement		a (in.)	Reinforcement		a (in.)	Reinforcement	
						Long Way	Short Way		Long Way	Short Way		Long Way	Short Way
9		20	160	21	12	15-½"φ	15-½"φ	10	8-¾"φ	8-¾"φ	9	8-¾"φ	8-¾"φ
		30	246	27	14	17-½"φ	17-½"φ	12	8-¾"φ	8-¾"φ	11	9-¾"φ	9-¾"φ
		40	334	31	16	20-½"φ	20-½"φ	14	10-¾"φ	10-¾"φ	13	10-¾"φ	10-¾"φ
		50	421	34	18	23-½"φ	23-½"φ	16	11-¾"φ	11-¾"φ	15	11-¾"φ	11-¾"φ
		60	509	36	20	26-½"φ	26-½"φ	18	12-¾"φ	12-¾"φ	17	12-¾"φ	12-¾"φ
10		20	174	25	12	17-½"φ	12-½"φ	12	11-⅝"φ	7-⅝"φ	11	11-⅝"φ	7-⅝"φ
		30	268	31	14	19-½"φ	14-½"φ	14	13-⅝"φ	8-⅝"φ	13	13-⅝"φ	8-⅝"φ
		40	366	34	16	24-½"φ	18-½"φ	15	16-⅝"φ	10-⅝"φ	14	16-⅝"φ	10-⅝"φ
		50	461	37	18	22-⅝"φ	16-⅝"φ	17	17-⅝"φ	11-⅝"φ	16	17-⅝"φ	11-⅝"φ
		60	559	40	20	24-⅝"φ	19-⅝"φ	19	18-⅝"φ	13-⅝"φ	18	18-⅝"φ	13-⅝"φ
11		20	191	27	12	14-⅝"φ	14-½"φ	11	9-¾"φ	9-⅝"φ	10	9-¾"φ	9-⅝"φ
		30	296	33	14	18-⅝"φ	18-½"φ	13	11-¾"φ	10-⅝"φ	12	11-¾"φ	11-⅝"φ
		40	402	37	16	22-⅝"φ	22-½"φ	15	13-¾"φ	12-⅝"φ	14	10-⅞"φ	12-⅝"φ
		50	509	40	18	25-⅝"φ	26-½"φ	17	15-¾"φ	14-⅝"φ	16	11-⅞"φ	13-⅝"φ
		60	617	43	20	23-¾"φ	23-⅝"φ	19	16-¾"φ	16-⅝"φ	18	12-⅞"φ	14-⅝"φ
12		20	209	26	14	18-⅝"φ	16-½"φ	12	11-¾"φ	10-⅝"φ	11	11-¾"φ	10-⅝"φ
		30	322	33	15	21-⅝"φ	18-½"φ	14	13-¾	12-⅝"φ	13	13-¾"φ	12-⅝"φ
		40	436	39	17	25-⅝"φ	21-½"φ	16	14-¾"φ	13-⅝"φ	15	14-¾"φ	13-⅝"φ
		50	552	43	19	28-⅝"φ	24-½"φ	18	16-¾"φ	15-⅝"φ	17	16-¾"φ	15-⅝"φ
		60	669	47	21	25-¾"φ	26-½"φ	20	17-¾"φ	16-⅝"φ	19	16-¾"φ	16-⅝"φ

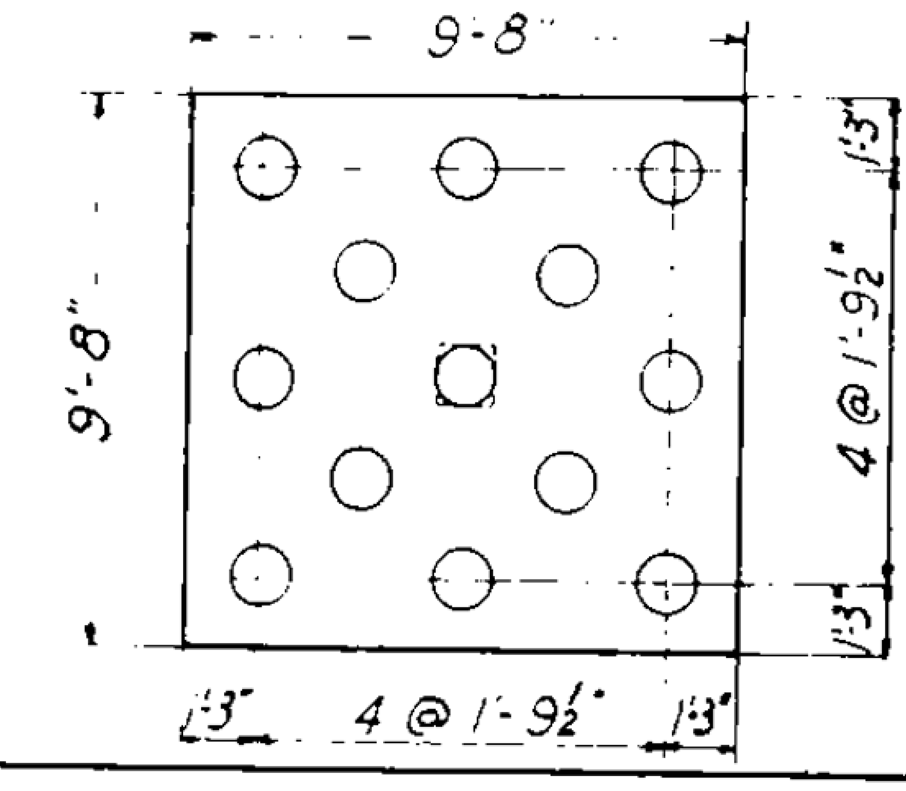
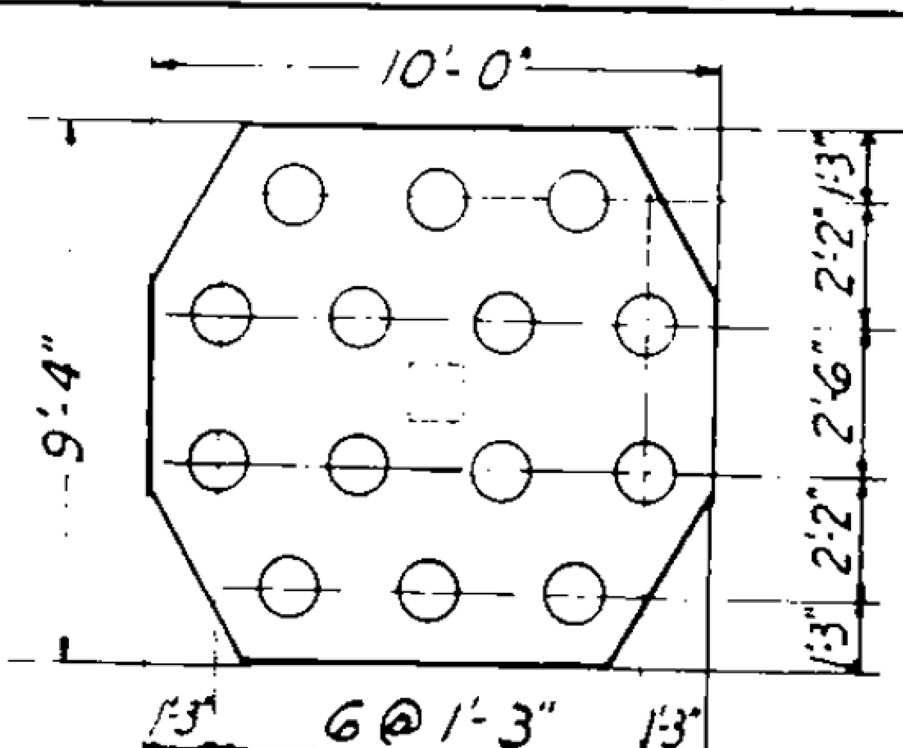
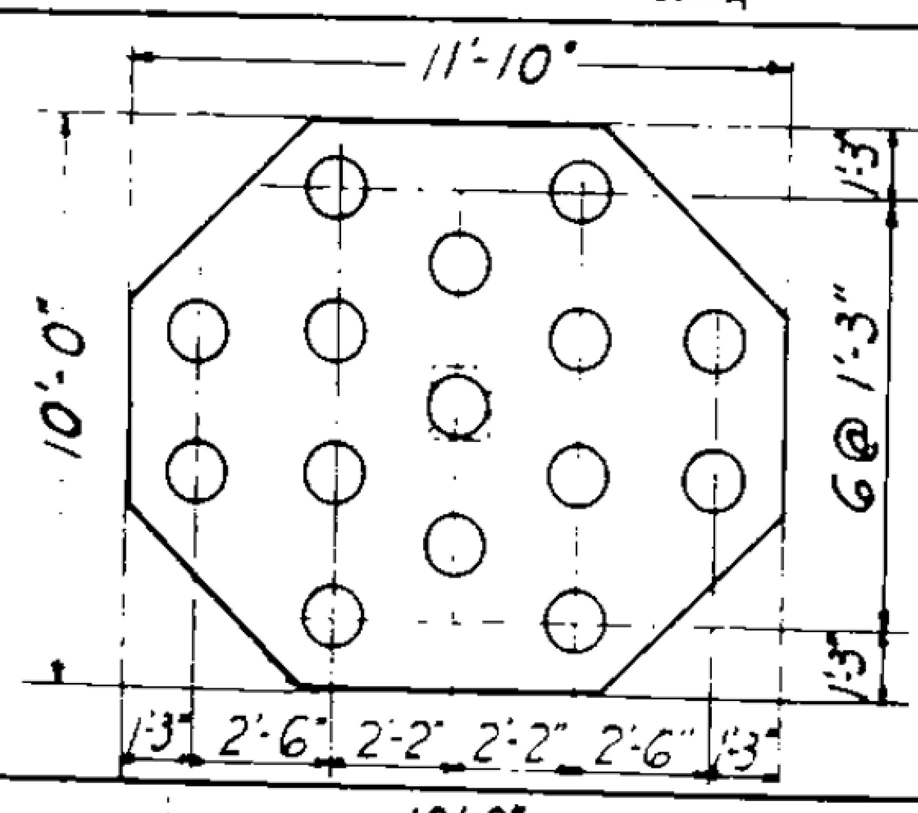
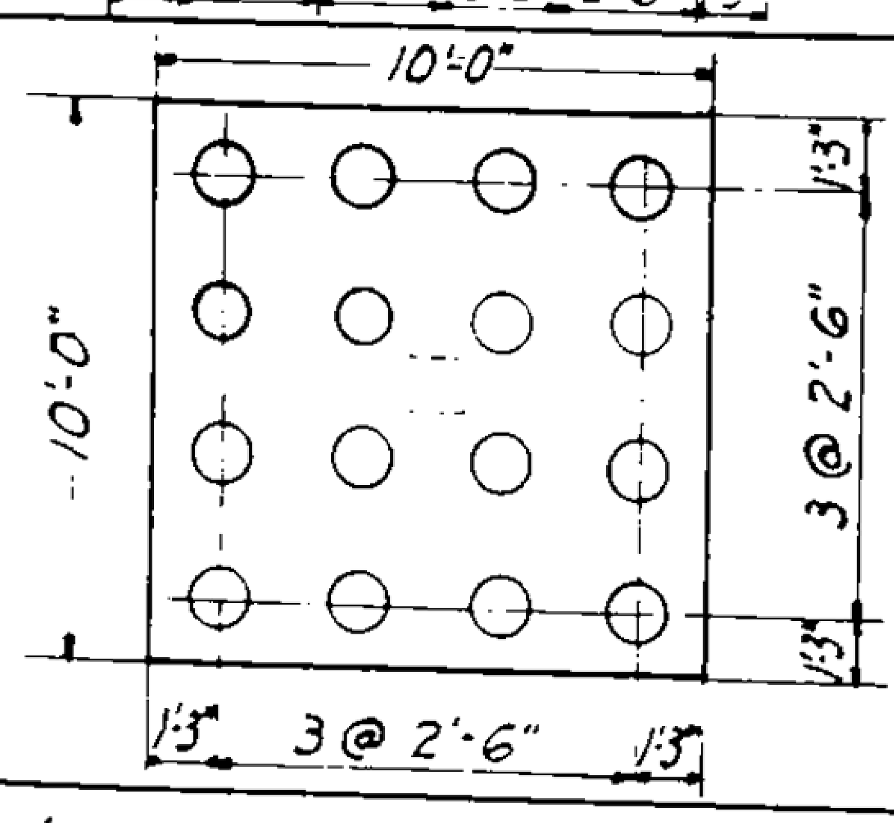
* Based on A.C.I. Code - 1941.

STRUCTURAL - FOUNDATIONS

PILE FOOTINGS.



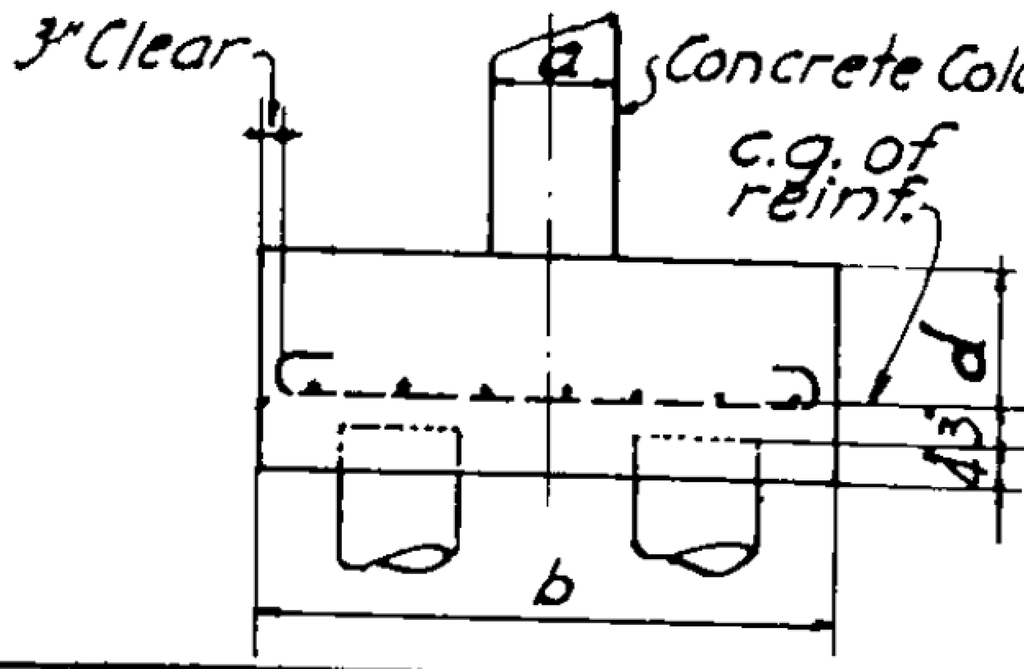
DESIGN DATA.		
f'_c = 2,000#/□"	f'_c = 3,000#/□"	f'_c = 3,750#/□"
f_c = 900#/□"	f_c = 1,350#/□"	f_c = 1,688#/□"
f_s = 20,000#/□"	f_s = 20,000#/□"	f_s = 20,000#/□"
v = 60#/□"	v = 75#/□"	v = 75#/□"
u = 112.5#/□"	u = 168#/□"	u = 200#/□"

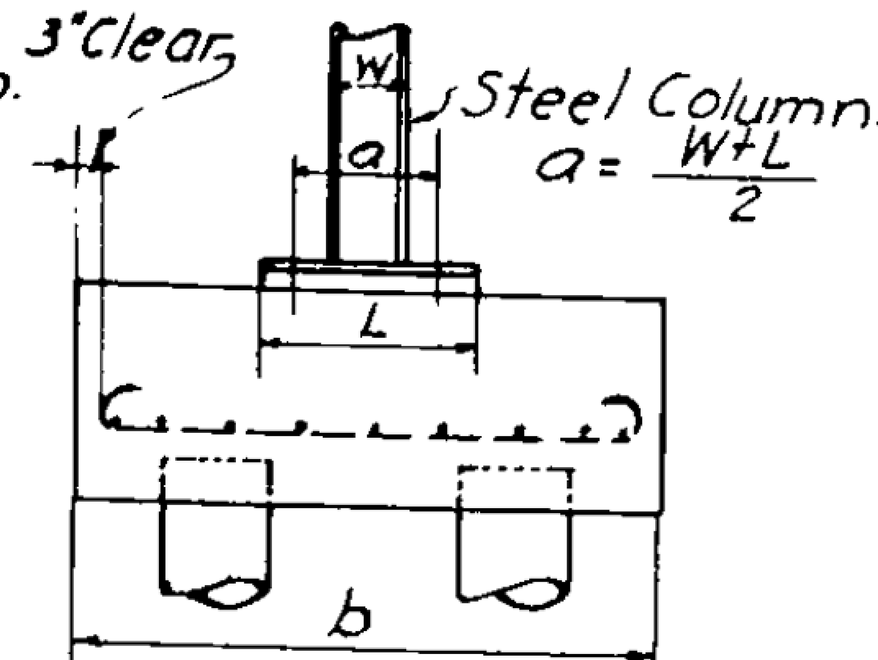
Number of Piles	Plan	For All Footings: Pile Value in Kips	For All Footings: Column Load in Kips	d (In.)	f'_c = 2,000#/□": a (In.)	f'_c = 2,000#/□": Reinforcement Long Way	f'_c = 2,000#/□": Reinforcement Short Way	f'_c = 3,000#/□": a (In.)	f'_c = 3,000#/□": Reinforcement Long Way	f'_c = 3,000#/□": Reinforcement Short Way	f'_c = 3,750#/□": a (In.)	f'_c = 3,750#/□": Reinforcement Long Way	f'_c = 3,750#/□": Reinforcement Short Way
13		20	221	24	14	16-5/8"φ	16-5/8"φ	12	11-3/4"φ	11-3/4"φ	11	9-7/8"φ	9-7/8"φ
		30	348	29	16	20-5/8"φ	20-5/8"φ	15	14-3/4"φ	14-3/4"φ	14	11-7/8"φ	11-7/8"φ
		40	475	32	18	25-5/8"φ	25-5/8"φ	17	17-3/4"φ	17-3/4"φ	16	13-7/8"φ	13-7/8"φ
		50	602	34	20	30-5/8"φ	30-5/8"φ	19	19-3/4"φ	19-3/4"φ	18	14-7/8"φ	14-7/8"φ
		60	729	37	22	33-5/8"φ	33-5/8"φ	21	20-3/4"φ	20-3/4"φ	19	16-7/8"φ	16-7/8"φ
14		20	242	26	14	18-5/8"φ	20-5/8"φ	13	15-5/8"φ	15-5/8"φ	12	11-3/4"φ	11-3/4"φ
		30	375	32	16	22-5/8"φ	26-5/8"φ	16	18-5/8"φ	18-5/8"φ	14	13-3/4"φ	13-3/4"φ
		40	508	38	18	25-5/8"φ	29-5/8"φ	18	19-5/8"φ	20-5/8"φ	17	14-3/4"φ	14-3/4"φ
		50	643	42	22	27-5/8"φ	30-5/8"φ	20	21-5/8"φ	22-5/8"φ	19	15-3/4"φ	16-3/4"φ
		60	779	46	24	29-5/8"φ	32-5/8"φ	22	22-5/8"φ	23-5/8"φ	20	16-3/4"φ	17-3/4"φ
15		20	254	30	14	16-5/8"φ	22-1/2"φ	13	12-3/4"φ	13-5/8"φ	12	12-3/4"φ	13-5/8"φ
		30	400	34	16	21-5/8"φ	30-1/2"φ	16	11-7/8"φ	16-5/8"φ	15	11-7/8"φ	16-5/8"φ
		40	546	36	20	27-5/8"φ	37-1/2"φ	18	14-7/8"φ	21-5/8"φ	17	11-1"φ	19-5/8"φ
		50	693	38	22	32-5/8"φ	34-5/8"φ	20	16-7/8"φ	24-5/8"φ	19	12-1"φ	22-5/8"φ
		60	841	40	24	36-5/8"φ	37-5/8"φ	22	18-7/8"φ	26-5/8"φ	20	11-1"□	25-5/8"φ
16		20	279	26	14	24-5/8"φ	24-5/8"φ	14	14-3/4"φ	14-3/4"φ	13	10-7/8"φ	10-7/8"φ
		30	431	32	18	30-5/8"φ	30-5/8"φ	16	17-3/4"φ	17-3/4"φ	15	12-7/8"φ	12-7/8"φ
		40	585	37	20	34-5/8"φ	34-5/8"φ	18	20-3/4"φ	20-3/4"φ	17	14-7/8"φ	14-7/8"φ
		50	739	42	22	36-5/8"φ	36-5/8"φ	20	21-3/4"φ	21-3/4"φ	19	15-7/8"φ	15-7/8"φ
		60	894	46	25	37-5/8"φ	37-5/8"φ	22	22-3/4"φ	22-3/4"φ	21	16-7/8"φ	16-7/8"φ

* Based on A.C.I. Code - 1941.

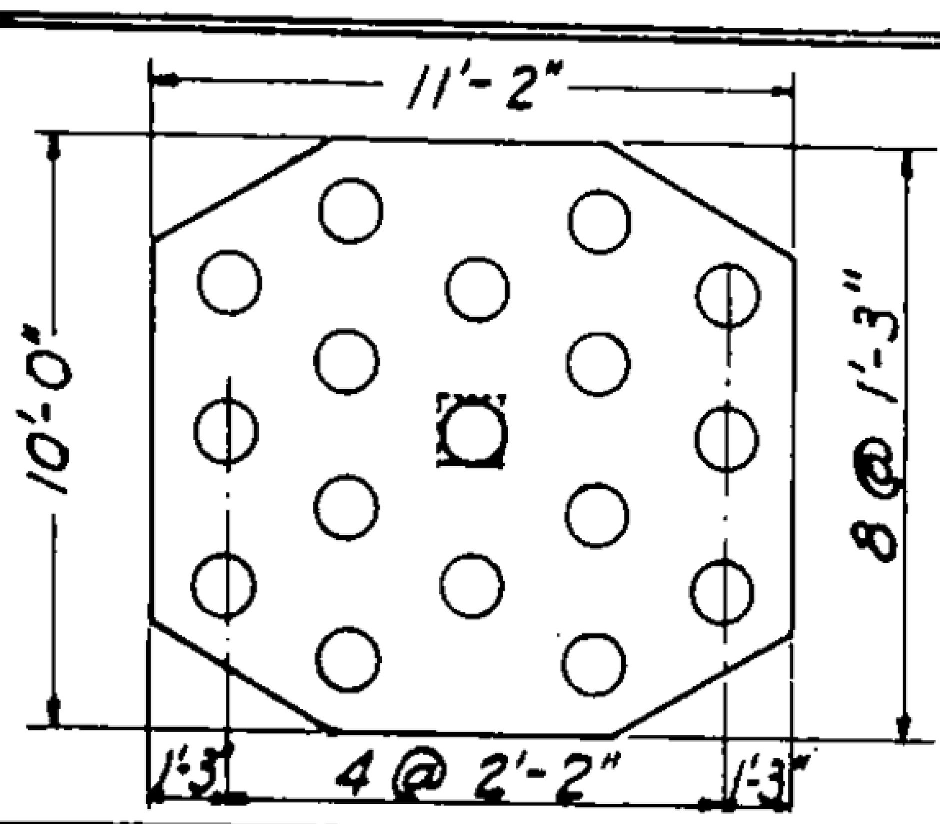
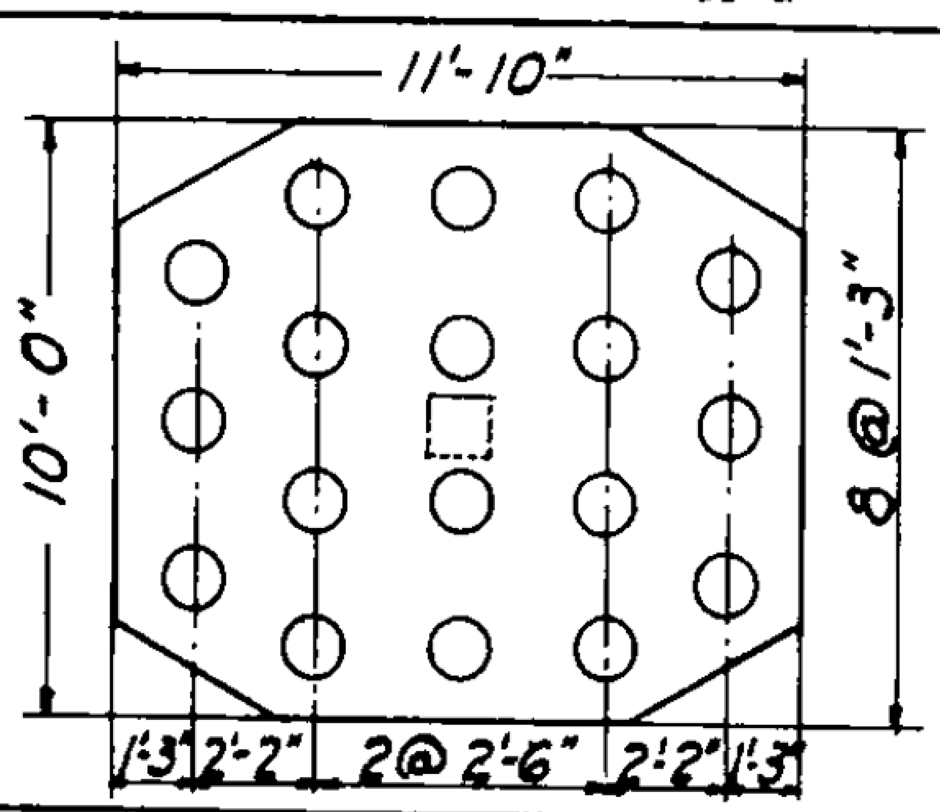
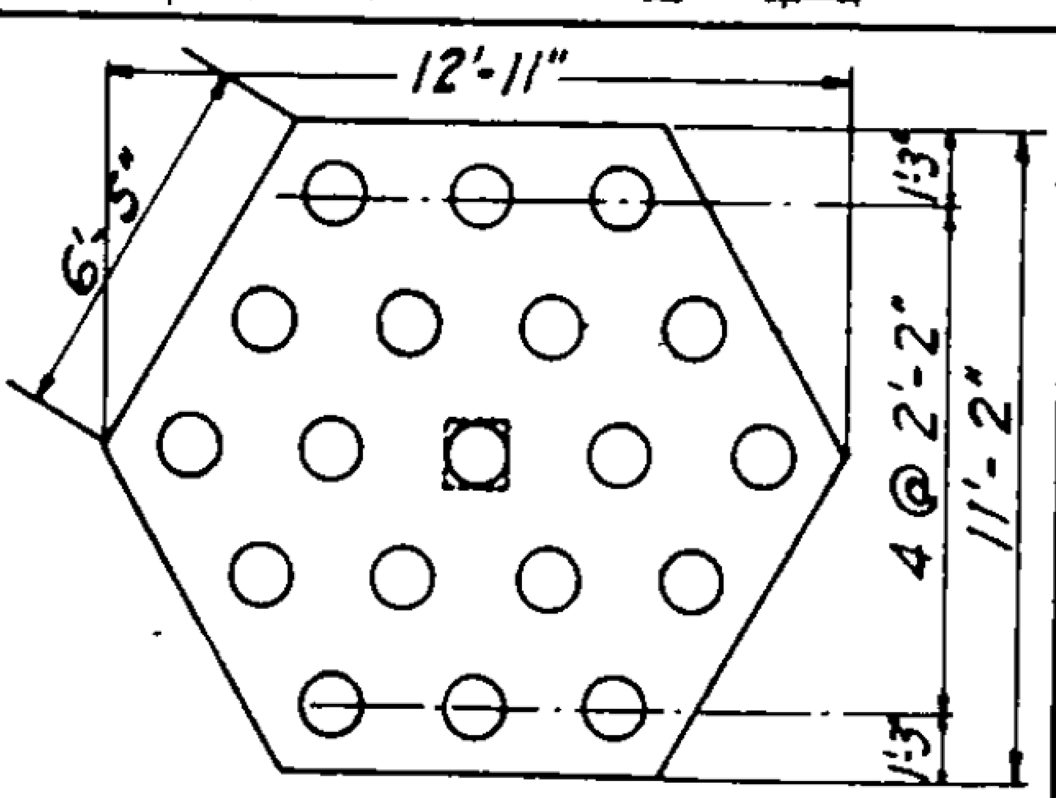
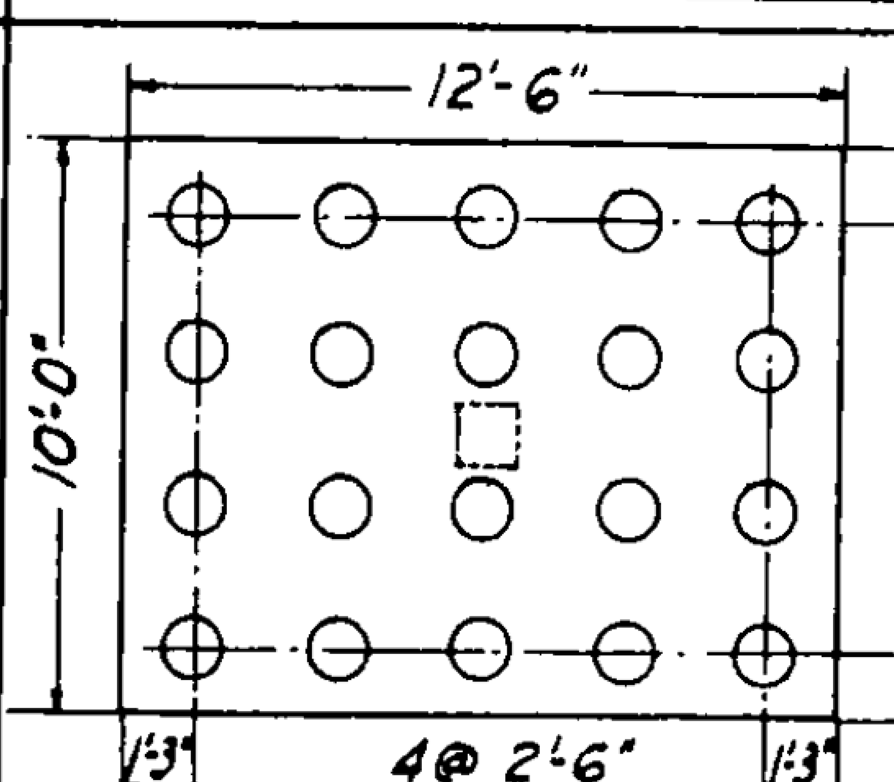
STRUCTURAL - FOUNDATIONS

PILE FOOTINGS.*





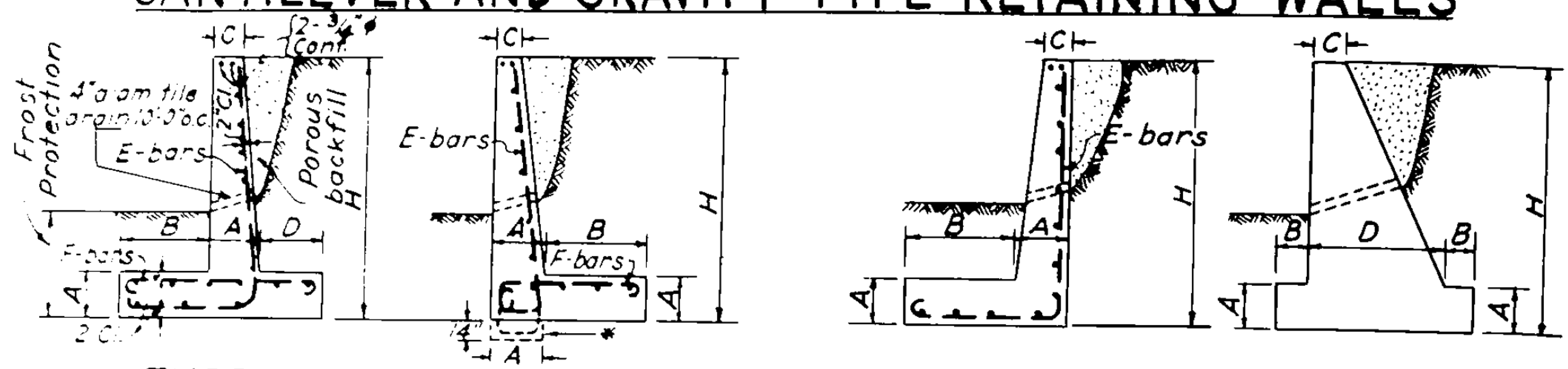
DESIGN DATA.		
f'_c = 2,000 #/□"	f'_c = 3,000 #/□"	f'_c = 3,750 #/□"
f_c = 900 #/□"	f_c = 1,350 #/□"	f_c = 1,688 #/□"
f_s = 20,000 #/□"	f_s = 20,000 #/□"	f_s = 20,000 #/□"
v = 60 #/□"	v = 75 #/□"	v = 75 #/□"
u = 112.5 #/□"	u = 168 #/□"	u = 200 #/□"

Number of Piles.	Plan	For All Footings: Pile Value in Kips	For All Footings: Column Load in Kips	For All Footings: d (in.)	f'_c = 2,000 #/□": a (in.)	f'_c = 2,000 #/□": Reinforcement Long Way	f'_c = 2,000 #/□": Reinforcement Short Way	f'_c = 3,000 #/□": a (in.)	f'_c = 3,000 #/□": Reinforcement Long Way	f'_c = 3,000 #/□": Reinforcement Short Way	f'_c = 3,750 #/□": a (in.)	f'_c = 3,750 #/□": Reinforcement Long Way	f'_c = 3,750 #/□": Reinforcement Short Way
17		20	290	32	14	18-5/8"ϕ	17-5/8"ϕ	14	9-7/8"ϕ	10-3/4"ϕ	13	9-7/8"ϕ	10-3/4"ϕ
		30	454	36	18	23-5/8"ϕ	23-5/8"ϕ	17	12-7/8"ϕ	13-3/4"ϕ	16	12-7/8"ϕ	9-7/8"ϕ
		40	620	40	20	28-5/8"ϕ	28-5/8"ϕ	19	15-7/8"ϕ	16-3/4"ϕ	18	11-1"ϕ	12-7/8"ϕ
		50	786	42	24	33-5/8"ϕ	32-5/8"ϕ	21	17-7/8"ϕ	18-3/4"ϕ	20	13-1"ϕ	13-7/8"ϕ
		60	952	45	26	38-5/8"ϕ	35-5/8"ϕ	23	19-7/8"ϕ	20-3/4"ϕ	21	14-1"ϕ	15-7/8"ϕ
18		20	307	34	14	19-5/8"ϕ	18-5/8"ϕ	14	8-1"ϕ	11-3/4"ϕ	13	8-1"ϕ	8-7/8"ϕ
		30	481	39	18	25-5/8"ϕ	24-5/8"ϕ	18	10-1"ϕ	13-3/4"ϕ	17	10-1"ϕ	10-7/8"ϕ
		40	656	43	22	29-5/8"ϕ	28-5/8"ϕ	20	12-1"ϕ	16-3/4"ϕ	19	12-1"ϕ	12-7/8"ϕ
		50	832	46	24	33-5/8"ϕ	32-5/8"ϕ	22	13-1"ϕ	19-3/4"ϕ	20	13-1"ϕ	14-7/8"ϕ
		60	1009	48	27	36-5/8"ϕ	35-5/8"ϕ	24	15-1"ϕ	21-3/4"ϕ	22	15-1"ϕ	15-7/8"ϕ
19		20	327	32	16	19-5/8"ϕ	19-5/8"ϕ	14	13-3/4"ϕ	13-3/4"ϕ	13	10-7/8"ϕ	10-7/8"ϕ
		30	512	37	18	26-5/8"ϕ	23-5/8"ϕ	18	16-3/4"ϕ	16-3/4"ϕ	17	12-7/8"ϕ	12-7/8"ϕ
		40	698	41	22	31-5/8"ϕ	28-5/8"ϕ	20	19-3/4"ϕ	19-3/4"ϕ	19	14-7/8"ϕ	14-7/8"ϕ
		50	886	43	26	36-5/8"ϕ	34-5/8"ϕ	22	22-3/4"ϕ	22-3/4"ϕ	21	16-7/8"ϕ	16-7/8"ϕ
		60	1071	45	27	40-5/8"ϕ	40-5/8"ϕ	24	25-3/4"ϕ	25-3/4"ϕ	23	18-7/8"ϕ	18-7/8"ϕ
20		20	332	36	16	16-3/4"ϕ	21-5/8"ϕ	15	12-7/8"ϕ	17-5/8"ϕ	14	9-1"ϕ	12-3/4"ϕ
		30	523	42	18	20-3/4"ϕ	28-5/8"ϕ	18	15-7/8"ϕ	21-5/8"ϕ	17	12-1"ϕ	15-3/4"ϕ
		40	719	45	22	25-3/4"ϕ	32-5/8"ϕ	20	19-7/8"ϕ	26-5/8"ϕ	19	14-1"ϕ	18-3/4"ϕ
		50	914	48	26	28-3/4"ϕ	35-5/8"ϕ	22	21-7/8"ϕ	22-3/4"ϕ	21	16-1"ϕ	20-3/4"ϕ
		60	1104	52	28	31-3/4"ϕ	37-5/8"ϕ	24	23-7/8"ϕ	23-3/4"ϕ	22	18-1"ϕ	22-3/4"ϕ

* Based on A.C.I. Code - 1941.

STRUCTURAL - FOUNDATIONS

CANTILEVER AND GRAVITY TYPE RETAINING WALLS



TYPE I　　TYPE II　　TYPE III　　TYPE IV

TYPE I

H	A	B	D	C	TOE PRESSURE	E-BARS	F-BARS
5'-0"	8"	1'-2"	6"	8"	765#/□'	3/8"φ-12" o.c.	3/8"φ-18" o.c.
6'-0"	8"	1'-5"	8"	8"	865 "	3/8"φ-12" o.c.	3/8"φ-18" o.c.
7'-0"	8"	1'-8"	10"	8"	930 "	3/8"φ- 9" o.c.	3/8"φ-18" o.c.
8'-0"	12"	1'-11"	9"	8"	1125 "	3/8"φ-11½" o.c.	3/8"φ-18" o.c.
9'-0"	12"	2'-2"	1'-0"	8"	1230 "	3/8"φ- 7½" o.c.	3/8"φ-18" o.c.
10'-0"	12"	2'-5"	1'-2"	8"	1315 "	1/2"φ-10" o.c.	3/8"φ-12" o.c.
11'-0"	12"	2'-8"	1'-5"	8"	1420 "	5/8"φ-10½" o.c.	3/8"φ-12" o.c.
12'-0"	12"	2'-11"	1'-8"	8"	1515 "	3/4"φ-12" o.c.	1/2"φ-14" o.c.
13'-0"	12"	3'-2"	1'-11"	10"	1630 "	7/8"φ-12" o.c.	1/2"φ-12" o.c.
14'-0"	12"	3'-5"	2'-2"	10"	1735 "	1"φ-12½" o.c.	1/2"φ-10" o.c.
15'-0"	14"	3'-8"	2'-3"	12"	1895 "	1"φ-12½" o.c.	1/2"φ-12" o.c.
16'-0"	15"	3'-11"	2'-4"	12"	2010 "	1"φ-11½" o.c.	1/2"φ-10" o.c.
17'-0"	16"	4'-2"	2'-6"	12"	2130 "	1"□-13" o.c.	1/2"φ- 9½" o.c.
18'-0"	17"	4'-4"	2'-7"	12"	2260 "	1"□-11½" o.c.	1/2"φ- 9½" o.c.
20'-0"	19"	4'-10"	2'-11"	12"	2510 "	1"□-10" o.c.	5/8"φ-10½" o.c.
22'-0"	21"	5'-4"	3'-3"	12"	2750 "	1"□- 8" o.c.	3/4"φ-11½" o.c.
24'-0"	24"	5'-10"	3'-5"	12"	3020 "	1"□- 7½" o.c.	3/4"φ-11½" o.c.
26'-0"	26"	6'-4"	3'-8"	12"	3240 "	1"□- 6" o.c.	3/4"φ-11" o.c.
28'-0"	28"	6'-10"	4'-0"	12"	3500 "	1"□- 5½" o.c.	3/4"φ- 9" o.c.
30'-0"	31"	7'-3"	4'-2"	12"	3780 "	1"□- 5" o.c.	3/4"φ- 9" o.c.

TYPE II

H	A	B	C	TOE PRESSURE	E-BARS	F-BARS
5'-0"	8"	2'-1"	8"	1170#/□'	3/8"φ-12" o.c.	3/8"φ-12" o.c.
6'-0"	8"	2'-7"	8"	1380 "	3/8"φ-12" o.c.	3/8"φ-12" o.c.
7'-0"	8"	3'-2"	8"	1610 "	3/8"φ- 9" o.c.	3/8"φ- 8" o.c.
8'-0"	12"	3'-7"	8"	1825 "	3/8"φ-11½" o.c.	3/8"φ- 8" o.c.
9'-0"	12"	4'-0"	8"	2030 "	1/2"φ-14" o.c.	1/2"φ-10½" o.c.
10'-0"	12"	4'-7"	8"	2230 "	1/2"φ-10" o.c.	5/8"φ-11" o.c.
*11'-0"	12"	5'-2"	8"	2440 "	5/8"φ-10½" o.c.	3/4"φ-12" o.c.
*12'-0"	12"	5'-9"	8"	2640 "	3/4"φ-12" o.c.	7/8"φ-12" o.c.
*13'-0"	12"	6'-4"	10"	2850 "	7/8"φ-12" o.c.	7/8"φ- 9½" o.c.
*14'-0"	12"	6'-11"	10"	3050 "	7/8"φ- 9½" o.c.	1"φ-10" o.c.
*15'-0"	14"	7'-3"	12"	3290 "	1"φ-12½" o.c.	1"φ-10½" o.c.
*16'-0"	15"	7'-8"	12"	3510 "	1"φ-11½" o.c.	1"□-12" o.c.
*17'-0"	16"	8'-3"	12"	3730 "	1"□-13" o.c.	1"□-10" o.c.
*18'-0"	18"	8'-6"	12"	3950 "	1"□-12½" o.c.	1"□-10" o.c.
20'-0"	20"	9'-6"	12"	4390 "	1"□-10" o.c.	1"□- 8" o.c.
22'-0"	22"	10'-5"	12"	4820 "	1"□- 8½" o.c.	1"□- 7" o.c.
24'-0"	25"	11'-3"	12"	5270 "	1"□- 7½" o.c.	1"□- 6" o.c.
26'-0"	28"	12'-2"	12"	5690 "	1"□- 7" o.c.	1"□- 5½" o.c.
28'-0"	30"	13'-1"	12"	6160 "	1"□- 6" o.c.	1"□- 4½" o.c.
30'-0"	33"	13'-10"	12"	6580 "	1"□- 5½" o.c.	1"□- 4" o.c.

TYPE III

H	A	B	C	TOE PRESSURE	E-BARS
5'-0"	8"	1'-8"	8"	572#/□'	3/8"φ-12" o.c.
6'-0"	8"	2'-5"	8"	545 "	3/8"φ-12" o.c.
7'-0"	8"	3'-3"	8"	525 "	1/2"φ-14" o.c.
8'-0"	12"	3'-2"	8"	720 "	3/8"φ-10" o.c.
9'-0"	12"	4'-1"	8"	694 "	1/2"φ-12" o.c.
10'-0"	12"	5'-0"	8"	675 "	5/8"φ-12½" o.c.
11'-0"	12"	6'-0"	8"	657 "	3/4"φ-13" o.c.
12'-0"	12"	7'-1"	8"	640 "	3/4"φ-10" o.c.
13'-0"	12"	7'-9"	10"	677 "	7/8"φ-11" o.c.
14'-0"	12"	9'-0"	10"	657 "	1"φ-11" o.c.
15'-0"	14"	8'-10"	12"	800 "	1"φ-11" o.c.
16'-0"	15"	9'-6"	12"	838 "	1"□-12" o.c.
17'-0"	16"	10'-3"	12"	875 "	1"□-11" o.c.
18'-0"	18"	10'-9"	12"	955 "	1"□-10½" o.c.
20'-0"	20"	12'-2"	12"	1030 "	1"□- 9" o.c.
22'-0"	22"	13'-8"	12"	1104 "	1"□- 7½" o.c.
24'-0"	25"	14'-10"	12"	1225 "	1"□- 6½" o.c.
26'-0"	28"	16'-2"	12"	1328 "	1"□- 6" o.c.
28'-0"	30"	17'-5"	12"	1425 "	1"□- 5" o.c.
30'-0"	33"	18'-7"	12"	1545 "	1"□- 4½" o.c.

TYPE IV

H	A	B	D	C	TOE PRESSURE
5'-0"	1'-0"	6"	1'-4"	8"	1046#/□'
6'-0"	1'-0"	6"	1'-8"	8"	1360 "
7'-0"	1'-0"	6"	2'-4"	8"	1540 "
8'-0"	1'-0"	6"	2'-10"	8"	1760 "
9'-0"	1'-0"	6"	3'-4"	8"	2040 "
10'-0"	1'-0"	6"	3'-10"	12"	2300 "
11'-0"	1'-0"	6"	4'-4"	12"	2560 "
12'-0"	1'-0"	6"	4'-10"	12"	2800 "
13'-0"	1'-0"	6"	5'-5"	12"	3040 "
14'-0"	1'-0"	6"	5'-11"	12"	3140 "
15'-0"	1'-0"	6"	6'-6"	12"	3500 "
16'-0"	1'-0"	6"	7'-0"	16"	3780 "
17'-0"	1'-0"	6"	7'-6"	16"	4040 "
18'-0"	1'-0"	6"	8'-0"	16"	4340 "
20'-0"	1'-0"	6"	9'-4"	16"	4750 "

Design based on weight of earth 100 lbs. per cu. ft. and angle of repose assumed 33° and no surcharge. Designed for 2000 lb. controlled concrete. A low water-cement ratio recommended for permanency. Will pass for New York City Class "B" concrete.

The resultant pressure on walls above is at the outer edge of middle third.

Alternate vertical E-bars in types I, II and III walls may be cut at ½ H.

Expansion joints in walls should not be over 75'-0" o.c.

For additional data on retaining walls, see pg. 3-21.

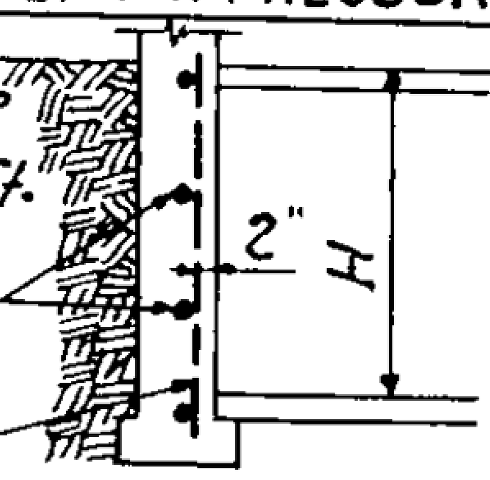
STRUCTURAL - FOUNDATIONS

BASEMENT RETAINING WALLS.

$f'_c = 2{,}000\ \#/\square''$ - $f_s = 20{,}000\ \#/\square''$

TABLE A - REINFORCEMENT FOR EARTH PRESSURE (DRY).

Angle of repose $\phi = 33°$
Earth $W = 100$ *lbs. per cu. ft.*



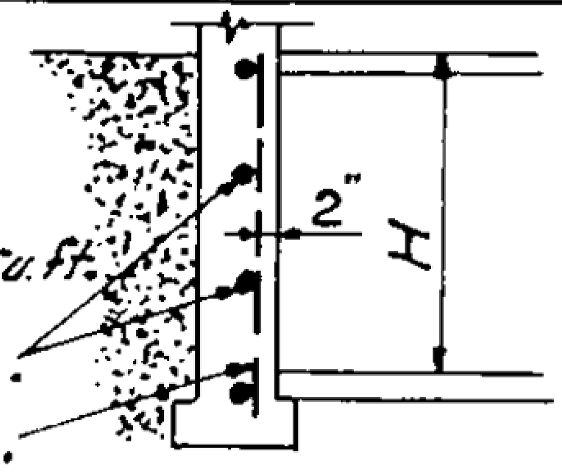
3/8"φ 18" o.c. Horiz.

Vertical steel in Table.

H	12" WALL	16" WALL	20" WALL
8'0"	3/8"φ - 12" o.c.	3/8"φ - 12" o.c.	3/8"φ - 12" o.c.
9'0"	3/8"φ - 12" o.c.	3/8"φ - 12" o.c.	3/8"φ - 12" o.c.
10'0"	3/8"φ - 10" o.c.	3/8"φ - 12" o.c.	3/8"φ - 12" o.c.
11'0"	3/8"φ - 7½" o.c.	3/8"φ - 11" o.c.	3/8"φ - 12" o.c.
12'0"	1/2"φ - 10½" o.c.	3/8"φ - 8" o.c.	3/8"φ - 10½" o.c.
13'0"	1/2"φ - 8" o.c.	1/2"φ - 12" o.c.	3/8"φ - 8½" o.c.
14'0"	5/8"φ - 10" o.c.	1/2"φ - 9" o.c.	1/2"φ - 12" o.c.
15'0"	5/8"φ - 8" o.c.	5/8"φ - 11" o.c.	1/2"φ - 9½" o.c.
16'0"	3/4"φ - 10" o.c.	5/8"φ - 9½" o.c.	1/2"φ - 7½" o.c.
17'0"	7/8"φ - 11" o.c.	3/4"φ - 11½" o.c.	5/8"φ - 10" o.c.
18'0"	7/8"φ - 9½" o.c.	3/4"φ - 9½" o.c.	5/8"φ - 8½" o.c.
19'0"	1"φ - 10½" o.c.	7/8"φ - 11" o.c.	3/4"φ - 10½" o.c.
20'0"	1"□ - 11½" o.c.	7/8"φ - 9½" o.c.	3/4"φ - 9" o.c.
21'0"		1"φ - 11" o.c.	7/8"φ - 10½" o.c.
22'0"		1"φ - 9½" o.c.	7/8"φ - 9" o.c.
23'0"		1"□ - 10½" o.c.	1"φ - 10½" o.c.
24'0"		1"□ - 9" o.c.	1"φ - 10" o.c.

TABLE B - REINFORCEMENT FOR SATURATED EARTH PRESS.

Saturated Earth, Assumed equivalent fluid weight $W' = 75$ *lbs. per cu. ft.*



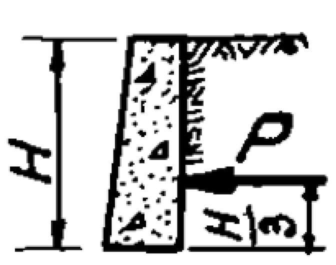
3/8"φ 18" o.c. Horiz.

Vertical steel in Table.

H	12" WALL	16" WALL	20" WALL
8'0"	3/8"φ - 7½" o.c.	3/8"φ - 11" o.c.	3/8"φ - 12" o.c.
9'0"	1/2"φ - 10" o.c.	3/8"φ - 7½" o.c.	3/8"φ - 9½" o.c.
10'0"	5/8"φ - 11" o.c.	1/2"φ - 10" o.c.	3/8"φ - 7" o.c.
11'0"	3/4"φ - 12" o.c.	5/8"φ - 11½" o.c.	1/2"φ - 9½" o.c.
12'0"	7/8"φ - 12" o.c.	5/8"φ - 9" o.c.	5/8"φ - 11½" o.c.
13'0"	7/8"φ - 10" o.c.	3/4"φ - 10" o.c.	5/8"φ - 9" o.c.
14'0"	1"φ - 10½" o.c.	7/8"φ - 11" o.c.	3/4"φ - 10" o.c.
15'0"		1"φ - 12" o.c.	7/8"φ - 11½" o.c.
16'0"		1"□ - 12" o.c.	7/8"φ - 9½" o.c.
17'0"		1"□ - 10" o.c.	1"φ - 10½" o.c.
18'0"		1"□ - 8½" o.c.	1"□ - 11" o.c.
19'0"			1"□ - 9½" o.c.
20'0"			1⅛"□ - 10" o.c.
21'0"			1¼"□ - 11" o.c.
22'0"			1¼"□ - 9½" o.c.

TABLE C - EARTH PRESSURES.

Angle of repose $\phi = 33°$
$W = 100$ *lbs. per cu. ft.*



$$P = \tfrac{1}{2} W H^2 \frac{1-\sin\phi}{1+\sin\phi}$$

per foot length of wall.
(Rankine)

H FEET	P LBS.	P/SQ.FT. MAX.	H FEET	P LBS.	P/SQ.FT. MAX.
5	370	147	14	2890	413
6	530	177	16	3770	472
7	720	206	18	4780	531
8	940	236	20	5900	590
9	1200	266	22	7130	649
10	1470	295	24	8490	708
11	1780	324	26	9960	766
12	2120	354	28	11560	825
13	2490	383	30	13260	885

TABLE D - SATURATED EARTH PRESS.

$W' = 75$ *lbs. per cu. ft.*

$$P = \tfrac{1}{2} W' H^2$$

per foot length of wall.

H FEET	P LBS.	P/SQ.FT. MAX.	H FEET	P LBS.	P/SQ.FT. MAX.
1	38	75	12	5400	900
2	150	150	13	6330	975
3	338	225	14	7350	1050
4	600	300	15	8440	1125
5	940	375	16	9600	1200
6	1350	450	17	10800	1275
7	1840	525	18	12150	1350
8	2400	600	19	13500	1425
9	3040	675	20	15000	1500
10	3750	750	21	16600	1575
11	4530	825	22	18100	1650

TABLE E - COAL PRESSURES.

Total Pressure for Depth H for Bituminous Coal on Vertical Walls. Weight per cu. ft. 50 lbs. $\phi = 35°$

H FEET	P LBS.	P/SQ.FT. MAX.	H FEET	P LBS.	P/SQ.FT. MAX.
5	170	68	11	820	149
6	240	81	12	980	163
7	330	95	14	1330	190
8	430	108	16	1730	217
9	550	122	18	2190	244
10	680	135	20	2710	271

__NOTE:__ Use Table A for permanent dry earth only. Interpolate between Tables A and B for seasonal rains resulting in saturated earth against walls.

For angles of repose see Pg. 3-23; for additional data on retaining walls, see Pg. 3-21.

SOILS - IDENTIFICATION OF PRINCIPAL TYPES

TABLE A - MAJOR DIVISIONS OF SOILS.

COARSE GRAINED (GRANULAR)		FINE GRAINED		ORGANIC	
GRAVEL	SAND	SILT	CLAY	MUCK	PEAT

TABLE B - IDENTIFICATION - VISUAL & BY TEXTURE.

GRAVEL

Rounded or waterworn pebbles or bulk rock grains. No cohesion. No plasticity. Gritty & granular. Crunchy under foot. As a soil, over 1/10" in size. As an aggregate, over 1/4" in size.

SAND

Granular, gritty, loose grains, passing № 10 and retained on № 270 sieve. Individual grains readily seen and felt. No plasticity or cohesion. When dry a cast formed in the hands will fall apart. When moist, a cast will crumble when touched. The coarse grains are rounded - the fine grains are visible and angular. As an aggregate for Construction Sand consists of mineral grains between 1/4" and 1/200".

SILT

Fine, barely visible grains, passing № 270 sieve and over .005 mm. in size. Little or no plasticity. No Cohesion. A dried cast is easily crushed in the hands. Permeable - movement of water through voids occurs easily and is visible. When mixed with water the grains will settle in from 30 min. to 1 hour. Feels gritty when bitten. Will not form a ribbon. Care must be used to distinguish fine sand from silt & fine silt from clay.

CLAY

Invisible particles under 0.005 mm. (or 0.002 mm. in M.I.T. scale) in size. Cohesive. Highly plastic when moist. When pinched between the fingers will form a long thin, flexible ribbon. Can be rolled into a thread to a pin point. When bitten with the teeth will not feel gritty. Will form hard lumps or clods when dry, difficult or impossible to crush in hands. Impermeable - no movement of water apparent through voids. Will remain suspended in water 3 hrs. to indefinitely.

MUCK and ORGANIC SILT

Thoroughly decomposed organic material with considerable mineral soil material. Usually black in color with a few fibrous remains. Odorous when dried and burnt. Found as deposits in swamps, peat bogs and muskeg. Easily identified. May contain some sand or silt.

PEAT

Partly decayed plant material. Mostly organic. Highly fibrous with visible plant remains.

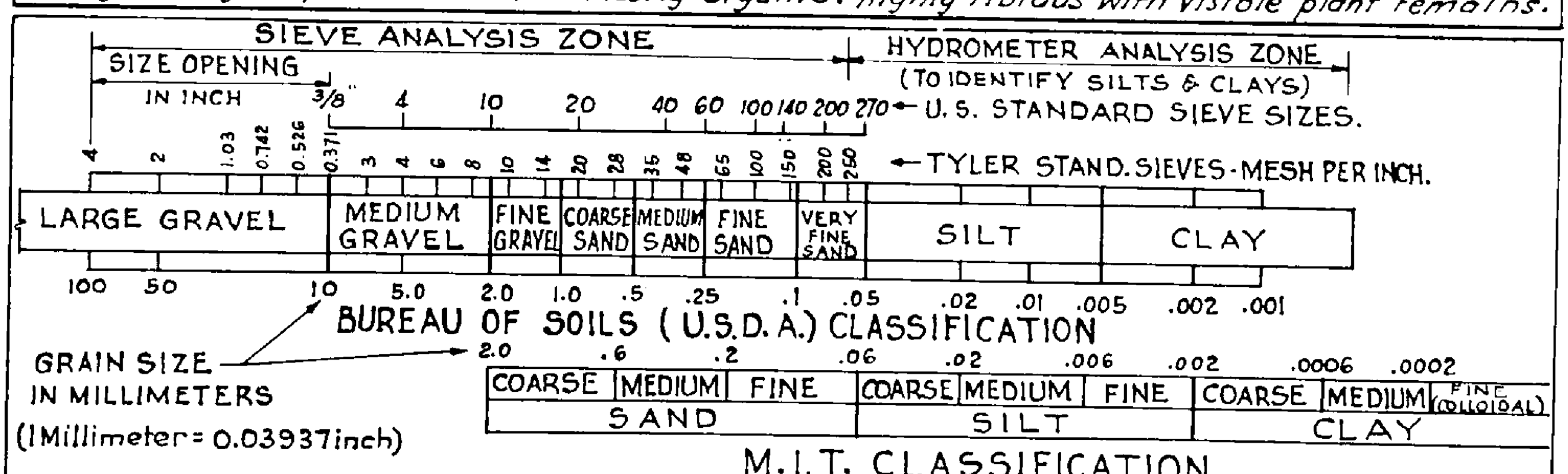


FIG. C - IDENTIFICATION BY MECHANICAL GRAIN SIZE ANALYSIS.

NOTES: Mechanical analysis is necessary to identify soils into the various divisions, and into PRA & Casagrande systems. In general, the value of soils as a foundation for structures and as a material of Construction is determined by the grain sizes and the gradation of the soil mixture. Other widely used grain size classifications are International, M.I.T., Natl. PK. Serv., A.S.T.M.

SOILS – CLASSIFICATION

TABLE A – CLASSIFICATION OF SOIL MIXTURES.*

CLASS	PER CENT SAND	PER CENT SILT	PER CENT CLAY
SAND	80-100	0-20	0-20
SANDY LOAM	50-80	0-50	0-20
LOAM	30-50	30-50	0-20
SILT LOAM	0-50	50-100	0-20
SANDY CLAY LOAM	50-80	0-30	20-30
CLAY LOAM	20-50	20-50	20-30
SILTY CLAY LOAM	0-30	50-80	20-30
SANDY CLAY	55-70	0-15	30-45
CLAY	0-55	0-55	30-100
SILTY CLAY	0-15	55-70	30-45

NOTE: Determine proportions of sand, silt & clay by sieve analysis or inspection. (Natural soils seldom exist separately as gravel, sand, silt, clay, but are found as mixtures.)

USE OF CHART.

Example:

Given: Soil Containing 28% Clay, 45% Silt, 27% Sand.

Required: Classification

Solution: Enter Clay at 28, Enter Silt at 45. Intersect at A in Clay Loam band. Soil is Clay Loam.

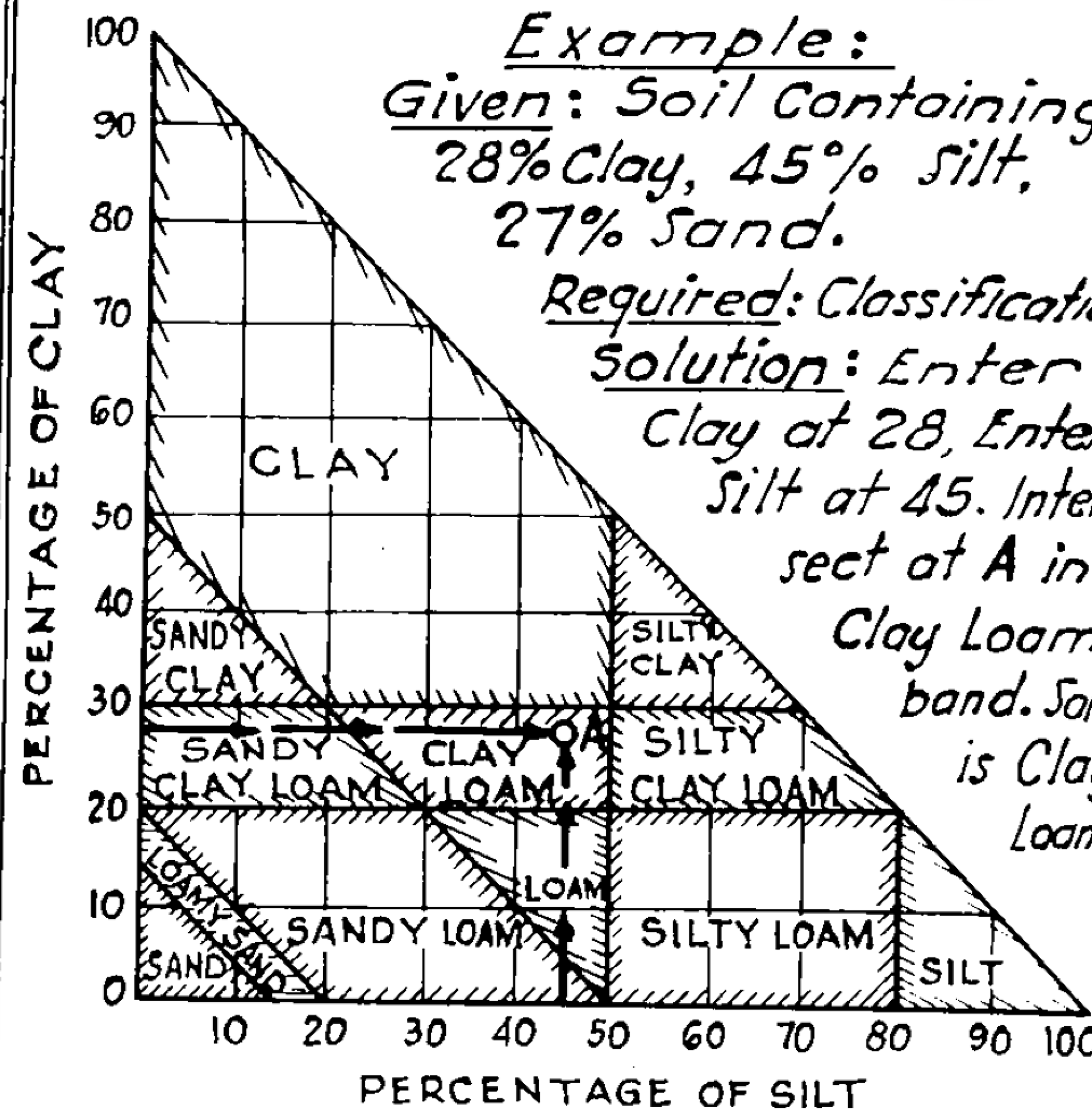
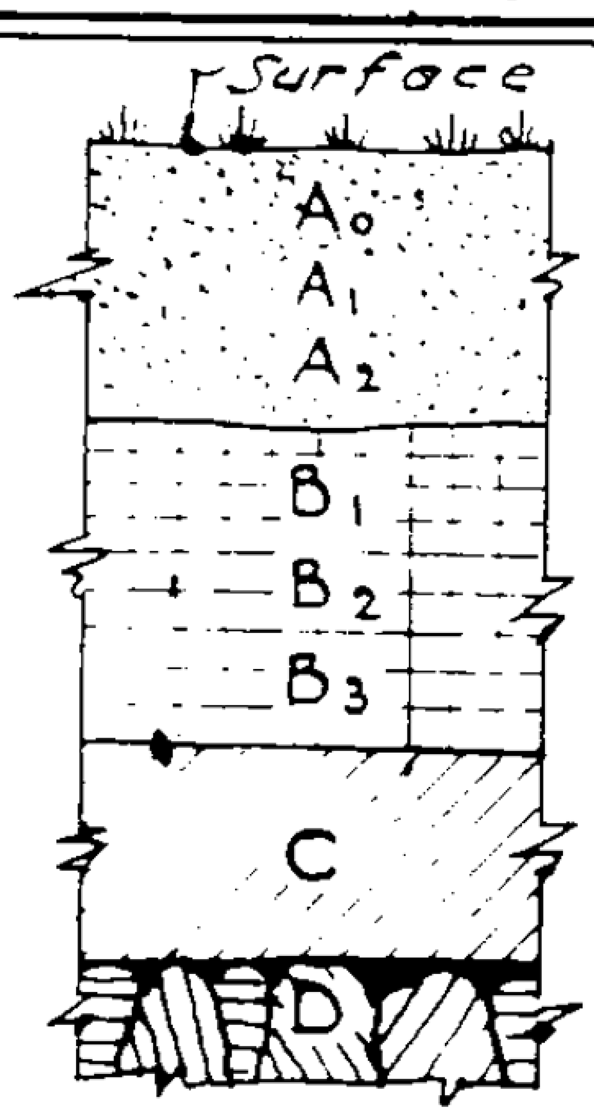


FIG. B-RIGHT ANGLE SOIL CHART. *



Soil Profile: A vertical cross-section of the soil layers from the surface downwards through the parent material.

A HORIZON The upper layer, surface soil or topsoil. The upper part is designated A_0 and is humus or organic debris. Indices are used for sub division into transition zones as shown for A_1, A_2, etc. May range to 24" in depth.

B HORIZON The heavier textured under layer or subsoil. May range from 6" to 8' in depth. May be subdivided into transition zones B_1, B_2, etc., as shown. The products of the leaching or eluviation of the A horizon may be deposited in horizon B.

C HORIZON The unweathered or incompletely weathered parent material.

D HORIZON The underlying stratum such as hard rock, hardpan, sand or clay.

FIG. C – CLASSIFICATION OF SOILS BY HORIZONS.*

Widely used in Soil stabilization.

NOTES: Structures or pavements are not usually placed on A horizon soils. Also the organic content of these soils may adversely affect stabilization. In cuts the C horizon soil does not usually have as good bearing value as the more weathered B horizon. Foundations for heavy structures are preferably founded on the D horizon where it is bedrock or unyielding.

TABLE D – CLASSIFICATION OF SOILS BY ORIGIN.

Residual:		Rock weathered in place - Wacke, laterite, podzols, residual sands, clays & gravels.
Cumulose		Organic accumulations - peat, muck, swamp soils, muskeg, humus, bog soils.
Transported	Glacial	Moraines, eskers, drumlins, Kames - till, drift, boulder clay, glacial sands & gravels.
Transported	Alluvial	Flood planes, deltas, bars - Sedimentary clays & silts, Alluvial sands & gravels.
Transported	Aeolian	Wind-borne deposits - Blow sands, dune sands, loess, adobe.
Transported	Colluvial	Gravity deposits - Cliff debris, talus, avalanches, masses of rock waste.
Transported	Volcanic	Volcanic deposits - Dakota bentonite, Volclay, Volcanic ash, lava.
Transported	Fill	Man made deposits - may range from waste & rubbish to carefully built embankments.

NOTE: In general, residual or glacial deposits are preferable for heavy foundations.

Important in soil surveys & Eng. Reports.

* Adapted from Soil Cement Laboratory Handbook, Portland Cement Assoc.

References: Engineering Geology, by Ries & Watson.

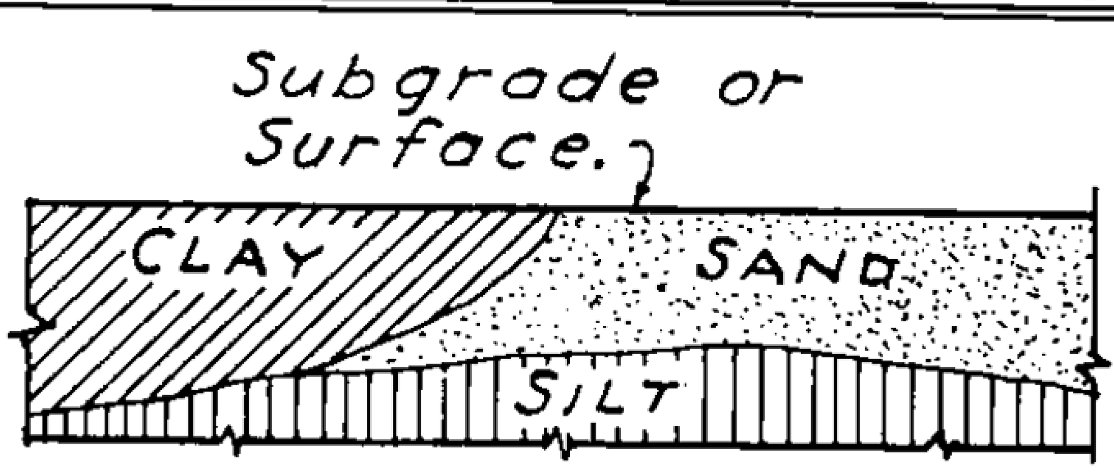
SOILS - P.R.A. CLASSIFICATION

TABLE A - CHARACTERISTICS FOR IDENTIFYING P.R.A. SOIL GROUPS.*

Established by Public Roads Administration & Highway Research Board. Classification as shown is latest modification. Extensively used by engr's for highways, airfields & dams.

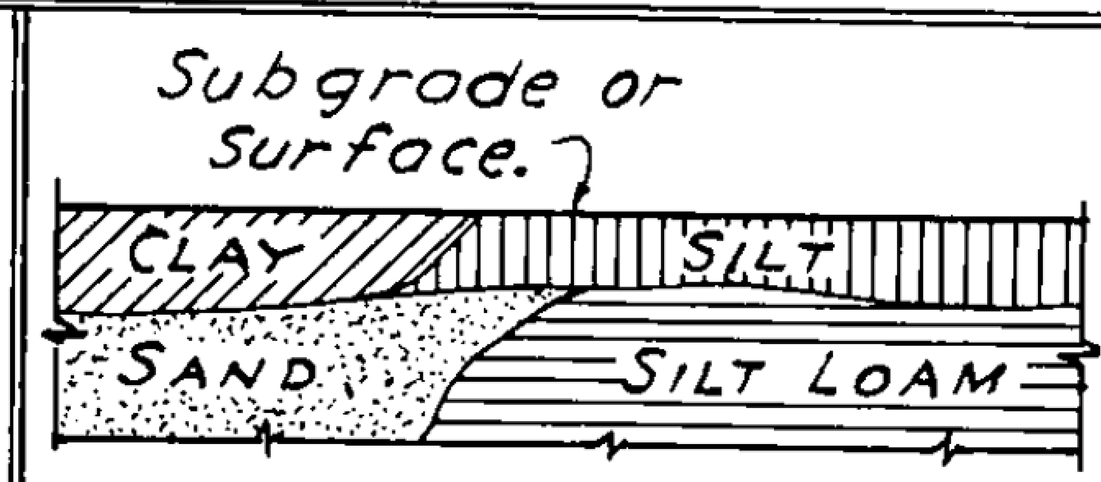
Characteristics \ Group		A-1 Non-Plastic	A-1 Plastic	A-2 Non-Plastic	A-2 Plastic	A-3	A-4 and A-4-7‡	A-5 and A-5-7‡	A-6	A-7	A-8
Textural Class		Uniformly graded granular coarse to fine		Poorly graded granular-coarse and fine		Clean sand or gravel	Silt or silt-loam	Silt or silt loam	Plastic clay	Plastic clay loam	Muck & peat
Soil Constants.	Internal Friction	High	High	High	High	High	Variable	Variable	Low	Low	Low
	Cohesion	High	High	Low	High	None	"	Low	High	High	Low
	Shrinkage	Not detrimental		Not Significant	Detrimental if poorly graded	Not Significant	"	Variable	Detrimental	Detrimental	Detrimental
	Expansion	None		None	Some	Slight	"	High	High	"	"
	Capillarity	"		"	"		Detrimental	"	"	High	"
	Elasticity	"		"	"	None	Variable	Detrimental	None	"	"
Capillary Rise		Low	High	36" Max.	Over 36"	6" Max.	High	High	High	High	"
Atterberg Limits	Liquid Limit	25 Max.	35 Max.	35 Max.	40 Max.	Non Plastic	40 Max.	Over 40	35 Min.	35 Min.	35-400
	Plasticity Index	6 Max.	4-9	NonPlastic	15 Max.	"	0-15	0-60	18 Min.	12 Min.	0-60
	Shrinkage Limit	14-20		15-25	25 Max.	Not Essential	20-30	30-120	6-14	10-30	30-120
Field Moisture Equivalent		Not Essential	Not Essential	Not Essential	Not Essential	Not Essential	30 Max.	30-120	50 Max.	30-100	30-400
Centrifuge Moisture Equivalent		15 Max.		12-25	25 Max.	12 Max.	Not Essential	Not Essential	Not Essential	Not Essential	Not Essential
Shrinkage Ratio		1.7-1.9		1.7-1.9	1.7-1.9	Not Essential	1.5-1.7	0.7-1.5	1.7-2.0	1.7-2.0	0.3-1.4
Volume Change		0-10		0-6	0-6	None	0-16	0-16	17 Min.	17 Min.	4-200
Lineal Shrinkage		0-3		0-2	0-4	"	0-4	0-4	5 Min.	5 Min.	1-30
Grading (Grain Size).	% Sand	70-85		55-80	55-80	75-100	55 Max.	55 Max.	55 Max.	55 Max.	55 Max.
	% Silt	10-20		0-45	0-45		High	Medium	Medium	Medium	Not
	% Clay	5-10		0-45	0-45		Low	Low	30 Min	30 Min.	Significant
	% Passing No. 10	20-100	40-100								
	% Passing No. 40	10-70	25-70								
	% Passing No. 200	3-25	8-25	Less than 35	Less than 35	0-10					

‡ A-4 or A-5 soil with A-7 characteristics.



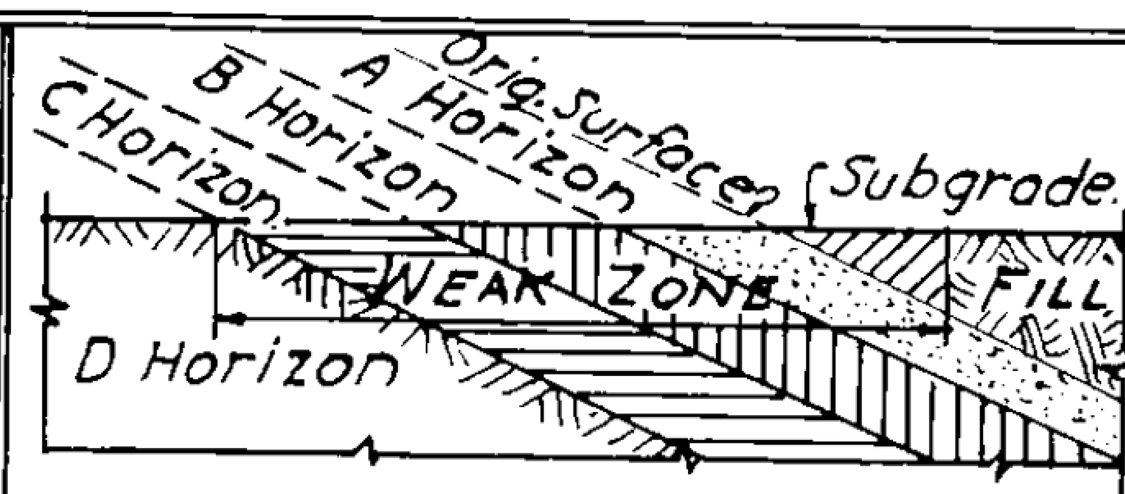
Rapid succession of soil types, pockets of different soil types. Changes in soil profile or changes in soil structure.
Non-uniform support.

GROUP B-1



Adjacent parts of fills constructed of widely differing soil types, as where hauling is from different sources.
Non-uniform support & settlement.

GROUP B-2



Cut through side hill creating sub grade on several types of natural soil and on fill within a short space.
Non-uniform support & settlement.

GROUP B-3

FIG. B - CLASSIFICATION OF NON-UNIFORM SUBGRADE SOILS.*

See Page 3-04 for treatment of these Subgrade Groups.

*Adapted from Public Roads Administration & Highway Research Board Publications.

SOILS-CHARACTERISTICS & PERFORMANCE-P.R.A. GROUPS

TABLE A

SOIL GROUP	A-1 Non Plastic	A-1 Plastic	A-2 Non Plastic	A-2 Plastic	A-3	A-4 and A-4-7†	A-5 and A-5-7†	A-6	A-7	A-8
Stability	High	High when dry	High	Good when dry	Ideal when Confined	Good When dry	Doubtful	Good, when properly compacted or undisturbed		None
Base	Good	Fair	Fair	Fair	Excellent	N.G.	N.G.	N.G.	N.G.	N.G.
Sub-base	Excellent	Good	Excellent	Good	"	"	"	"	"	"
Sub-grade	"	"	"	"	"	Poor	Poor	Poor	Bad	"
Fills under 50'	"	Excellent	"	"	Good	Good to Poor	Poor to Very Poor	Bad	Fair to Poor	"
Fills over 50'	Good	Good	Good to Fair	Good to Fair	Good to Fair	Fair to Poor	Very Poor	Bad	Very Poor	"
Frost Action	Slight	Subject to	Slight	Subject to	None	Bad	Bad	Slight to Bad	Slight to Bad	Slight
Dry Density	over 130 lb.	over 130 lb.	120-130 lb.	120-130 lb.	120-130 lb.	110-120 lb.	80-100 lb.	80-110 lb.	80-110 lb.	Under 90 lb.
Optimum Moisture	9%	9%	9-12%	9-12%	9-12%	12-17%	22-30%	17-28%	17-28%	—
Required Compaction	90-95%	90-95%	90-95%	90-95%	90-95%	95%	100%	100%	100%	Waste
Compaction Methods	Rolling with smooth face, tamping or rubber tire roller.				Tractor, Disking, Vibration.	Tamping or Sheeps-foot roller.	Tamping or Rubber tire roller.	Heavy Sheeps foot or tamping roller.		"
Compaction Abilities	Excellent	Excellent	Good with close control		Good	Poor to Good	Very Poor	Poor to Good	Poor to Fair	N.G.
Pumping Action	None	Slight	None	Slight	None			Bad	Bad	—
Bearing Value	Good to Excellent	Good to Excellent	Fair to Excellent			Poor to Fair	Poor	Poor	Poor	N.G.
Drainage	Drains Freely	Impervious	Fair to practically impervious		Drains Freely	Fair to Impervious	Fair to Impervious	Impervious	Poor	Poor
Flex Pavement & Base Required	0"-6"	0"-6"	0"-6"	2"-8"	0"-6"	9"-18"	9"-24"	12"-24"	12"-24"	

† A-4 or A-5 soil with A-7 characteristics.

NOTES: **A-1 to A-3 Soils:** When used as base, Plasticity Index and Liquid Limit should not exceed 6 and 25 respectively. **A-1 to A-3 Soils**: Best for soil cement stabilizing, use 8 to 12% cement. **Non-plastic A-1 to A-3 Soils**: May require vibration and saturation for compaction. **A-4 to A-7 Soils**: Fills should be placed in dry season at not over optimum moisture content. **A-4 Silts**: Will settle rapidly in fills and are liable to erosion. **A-5 Soils**: Very difficult to compact because of expansion and rebound. **A-6 Soils** (clays): Will pump badly into porous bases, cracks and R.R. ballast. Fills will settle over long period of time. High banks in cuts and fills very liable to slide.

TREATMENT FOR NON-UNIFORM SUB-GRADES. (See Pg. 3-03)

B-1: Loosen, pulverize, mix and recompact the soil to maximum density or remove to depth of 12" to 36" and substitute uniform base course material. Provide adequate sub-drainage for water trapped in perches or porous pockets.

B-2: Avoid this condition if possible. If unavoidable provide a uniform base of selected soil or thoroughly manipulate the soil for 12" to 24" depth and recompact to maximum density.

B-3: Provide a uniform layer of base material 18" to 36" deep across the weak zone. Compact the fill to same density as adjacent bank. Provide outlet sub-drainage for seepage that is following porous soil strata or moving between strata.

References: Engineering Properties of Soil by C.A. Hogentogler.
" " Highway Subgrades by A.G. Bruce.
" " Public Roads, Public Roads Administration.
" " Wartime Road Problems, Highway Research Board.

SOILS – USE & TREATMENT – P.R.A. GROUPS

TABLE A –	FOR ROADS AND AIRFIELDS. See also Table A-Pg. 3·06
A-1 SOILS:	Well graded gravels & Sand-clays, as Florida sand-clay or Georgia Topsoil. Satisfactory treated Surface. Good base with thin pavement. Excellent fill. Frost heave & break-up in North if plastic. Use sub-drainage to lower water table. Stabilize: mechanically, chlorides or Portland Cement.
A-2 SOILS:	Poorly graded sands & gravels, as S. Carolina Topsoil or Bank Run. Good base for moderate flexible or thin rigid pavement. Good fill. Frost heave, break-up if plastic. Softens when wet if plastic. Use base course when subgrade P.I. > 6. Sub-drainage effective. Stabilize: with bitumen, chlorides, Cement or Admixture soils.
A-3 SOILS:	Clean Sands & Gravels, as Florida Sand, glacial gravel, beach sand, wash gravel. Ideal base for moderate flexible or thin rigid pavement. Good fill. No frost heave or break up. Sub-drainage only thru impervious shoulders. Stabilize: with soil binder, bituminous, or chemical admixtures.
A-4 SOILS:	Silty soils as N.H. silt or Minn. Silt. No good for surface. Poor base. Absorbs water. Unstable when wet. Bad frost heave & break-up. Use Sub-drainage and/or base and Sub-base with flexible pavement. Use bituminous sub-grade prime. Use thick concrete pavement (7" to 10") with steel reinforcement and crack control.
A-5 SOILS:	Elastic silts as N. Carolina micaceous silt or Maryland micaceous Sandy loam. Use Sub-drainage and/or granular base and sub-base with bitum. Sub-grade prime. Use thick Conc. pavement reinforced with crack Control.
A-6 SOILS:	Clays, as Miss. Gumbo, Missouri collodial clay, sandy clays. Impermeable & stable when dry and undisturbed (hard clay). Plastic & absorbent if disturbed. Bad pumping into porous base, Macadam or pavement joints. Shrinks & cracks when dry. Use granular base & sub-base. Use sub-drainage only when made pervious by cracks, root holes & laminations. Frost heave slight when impermeable, bad when pervious. Use Sub-grade prime. Use thick, strong, dense flexible pvmt. or reinf'd. Crack controlled Concrete.
A-7 SOILS:	Expansive, plastic clays, as Adobe, Missouri Clay, Illinois or Red River Gumbo. Excessive Volume change. Bad frost heave & break up. Sub-drainage not effective. Use thick, dense flexible pavement with base & sub-base over sub-grade prime or reinforced crack controlled concrete placed on impervious paper.
A-8 SOILS:	Muck & Peat. No good for construction purposes. Excavate to solid stratum & replace with selected fill. Displacement by superimposed fill is doubtful. Displacement by explosive under superimposed fill is sometimes effective.

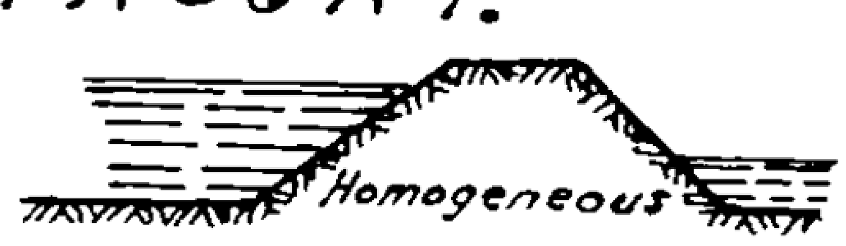
USE AS FOUNDATIONS FOR STRUCTURES.

A-1 to A-3 Soils: BEST. A-6 & A-7 Soils: NEXT BEST, when hard, undisturbed & not plastic. A-5, A-8, Plastic A-6 & A-7 Soils: Require special treatment in each case.

USE IN EARTH DAM.†

HOMOGENEOUS TYPE LOW PERCOLATION.

Use: A-1, A-2 Plastic, A-4 Plastic, Better grades of A-6 & A-7.



IMPERVIOUS CORE TYPE.

CORE.

Use: A-1, A-2 Plastic, A-4 Plastic, Better grades of A-6 & A-7.

POROUS FACES.

Non Plastic A-2 & A-4.

Do not use: A-3, A-5, A-8 or Highly Plastic A-6 or A-7 in Dam Construction. A-4, A-6 & A-7 Soils: Use Controlled compaction to maximum density at optimum moisture content.

† Adapted from Hogentogler, Engineering Properties of Soil, McGraw-Hill, Refs.-Highway Subgrades by A.G. Bruce, Principles of Highway Const., Public Rds. Adm., Highway Research Board – Wartime Road Problems.

SOILS - CASAGRANDE

TABLE A - CASAGRANDE

Major Division		Soil Group Symbols	Soil Groups & Typical Names	General Identification: Dry Strength	General Identification: Other Pertinent Examinations	Observations and Tests Relating to Material in Place	Principal Classification Tests on Disturbed Samples
Coarse-Grained Soils.	Gravel & Gravelly Soils.	G W	Well-graded gravel and gravel-sand mixtures; little or no fines.	None.	Gradation, Grain shape.	Dry unit weight or void ratio; degree of compaction; cementation; durability of grains; stratification and drainage characteristics; ground-water conditions; traffic tests; large-scale load tests; or California bearing tests.	Sieve analysis.
		G C	Well-graded gravel-sand-clay mixtures; excellent binder.	Medium to High	Gradation, grain shape, binder examination, wet & dry.		Sieve analysis, liquid and plastic limits on binder.
		G P	Poorly graded gravel & gravel-sand mixtures; little or no fines.	None.	Gradation, grain shape.		Sieve analysis.
		G F	Gravel with fines, very silty gravel, clayey gravel, poorly graded gravel-sand-clay mixtures.	Very slight to high.	Gradation, grain shape, binder examination, wet and dry.		Sieve analysis, liquid and plastic limits on binder if applicable.
	Sands & Sandy Soils.	S W	Well-graded sands & gravelly sands; little or no fines.	None.	Gradation, grain shape.		Sieve analysis.
		S C	Well-graded sand-clay mixtures; excellent binder.	Medium to high.	Gradation, grain shape, binder exam. wet & dry.		Sieve analysis, liquid & plastic limits on binder.
		S P	Poorly graded sands; little or no fines.	None.	Gradation, grain shape.		Sieve analysis.
		S F	Sand with fines, very silty sands, clayey sands, poorly graded sand-clay mixtures.	Very slight to high.	Gradation, grain shape, binder examination, wet and dry.		Sieve analysis, liquid and plastic limits on binder if applicable.
Fine-Grained Soils (containing little or no coarse grained material).	Fine-grained soils having low to medium compressibility.	M L	Silts (inorganic) and very fine sands, Mo, rock flour, silty or clayey fine sands with slight plasticity.	Very slight to medium.	Examination wet (shaking test and plasticity).	Dry unit weight, water content, and void ratio. Consistency undisturbed and remoulded. Stratification. Root holes. Fissures, etc. Drainage and ground-water condition. Traffic tests, large-scale load tests, California bearing tests, or compression tests.	Sieve analysis, liquid and plastic limits, if applicable.
		C L	Clays (inorganic) of low to medium plasticity, sandy clays, silty clays, lean clays.	Medium to high.	Examination in plastic range.		Liquid and plastic limits.
		O L	Organic silts and organic silt-clays of low plasticity.	Slight to medium.	Examination in plastic range, odor.		Liquid & plastic limits from natural condition and after oven-drying.
	Fine-grained soils having high compressibility.	M H	Micaceous or diatomaceous fine sandy and silty soils; elastic silts.	Very slight to medium.	Examination wet (shaking test and plasticity).		Sieve analysis, liquid & plastic limits if applicable.
		C H	Clays (inorganic) of high plasticity; fat clays.	High.	Examination in plastic range.		Liquid and plastic limits.
		O H	Organic clays of medium to high plasticity.	High.	Examination in plastic range, odor.		Liquid and plastic limits from natural condition and after oven-drying.
Fibrous organic soils with very high compressibility.		Pt	Peat and other highly organic swamp soils.	Readily identified.		Consistency, texture and natural water content.	

LEGEND FOR SOIL GROUP SYMBOLS.

C - Clay, plastic - inorganic soil.
F - Fines, material < 0.1 mm.
G - Gravel, gravelly soil.
H - High compressibility.
L - Relatively low to medium compressibility.
M - Mo, very fine sand, silt, rock flour.
O - Organic silt, silt clay or clay.
P - Poorly graded.
Pt - Peat, highly organic fibrous soil.
S - Sand, sandy soil.
W - Well graded.

CLASSIFICATION

SOIL CHART.

Value as Foundation When Not Subject to Frost Action	Value as Wearing Surface.*† With Dust Palliative.	Value as Wearing Surface.*† With Bit. Surf. Treat.	Potential Frost Action†	Shrinkage Expansion Elasticity	Drainage Characteristics	Compaction Characteristics & Equipment.	Solids at Optimum Compaction. u, lb/cu.ft.** e, Void Ratio	California Bearing Ratio for Compacted and Soaked Specimen	Comparable Group in Public Roads Class. (P.R.A.)
Excellent.	Fair to Poor.	Excellent.	None to very slight.	Almost none.	Excellent.	Excellent, Tractor.	$u > 125$ $e < 0.35$	> 50	A-3
Excellent.	Excellent.	Excellent.	Medium.	Very slight.	Practically impervious.	Excellent, Tamping Roller.	$u > 130$ $e < 0.30$	> 40	A-1
Good to Excellent.	Poor.	Poor to Fair.	None to very slight.	Almost none.	Excellent.	Good, Tractor.	$u > 115$ $e < 0.45$	25-60	A-3
Good to Excellent.	Poor to Good.	Fair to Good.	Slight to medium.	Almost none to slight.	Fair to practically impervious.	Good, Close Control Essential, Rubber Tired Roller, Tractor.	$u > 120$ $e < 0.40$	> 20	A-2
Excellent to Good.	Poor.	Good.	None to very slight.	Almost none.	Excellent.	Excellent, Tractor.	$u > 120$ $e < 0.40$	20-60	A-3
Excellent to Good.	Excellent.	Excellent.	Medium.	Very slight.	Practically impervious.	Excellent, Tamping Roller.	$u > 125$ $e < 0.35$	20-60	A-1
Fair to Good.	Poor.	Poor.	None to very slight.	Almost none.	Excellent.	Good, Tractor	$u > 100$ $e < 0.70$	10-30	A-3
Fair to Good.	Poor to Good.	Poor to Good.	Slight to high.	Almost none to medium.	Fair to practically impervious.	Good, Close Control Essential, Rubber Tired Roller.	$u > 105$ $e < 0.60$	8-30	A-2
Fair to Poor.	Poor.		Medium to very high.	Slight to medium.	Fair to poor.	Good to Poor, Close Control Essential, Rubber Tired Roller.	$u > 100$ $e < 0.70$	6-25	A-4
Fair to Poor.	Poor.		Medium to high.	Medium.	Practically impervious.	Fair to Good, Tamping Roller.	$u > 100$ $e < 0.70$	4-15	A-4 A-6 A-7
Poor.	Very Poor.		Medium to high.	Medium to high.	Poor.	Fair to Poor Tamping Roller.	$u > 90$ $e < 0.90$	3 - 8	A-4 A-7
Poor.	Very Poor.		Medium to very high.	High.	Fair to poor.	Poor to Very Poor.	$u > 100$ $e < 0.70$	< 7	A-5
Poor to very poor.	Very Poor.		Medium.	High.	Practically impervious.	Fair to Poor, Tamping Roller.	$u > 90$ $e < 0.90$	< 6	A-6 A-7
Very poor.	Useless.		Medium.	High.	Practically impervious.	Poor to Very Poor.	$u > 100$ $e < 0.70$	< 4	A-7 A-8
Extremely poor.	Useless.		Slight.	Very high.	Fair to poor.	Compaction not Practical. Replace with Compactible Material.			A-8

Notes:
* Values are for subgrade and base courses, except for base courses directly under wearing surface.
† Values are for guidance only. Design should be based on test results.
** Unit weights apply only to soils with specific gravities ranging between 2.65 and 2.75.

SOILS - CONSTANTS FOR PAVEMENT DESIGN

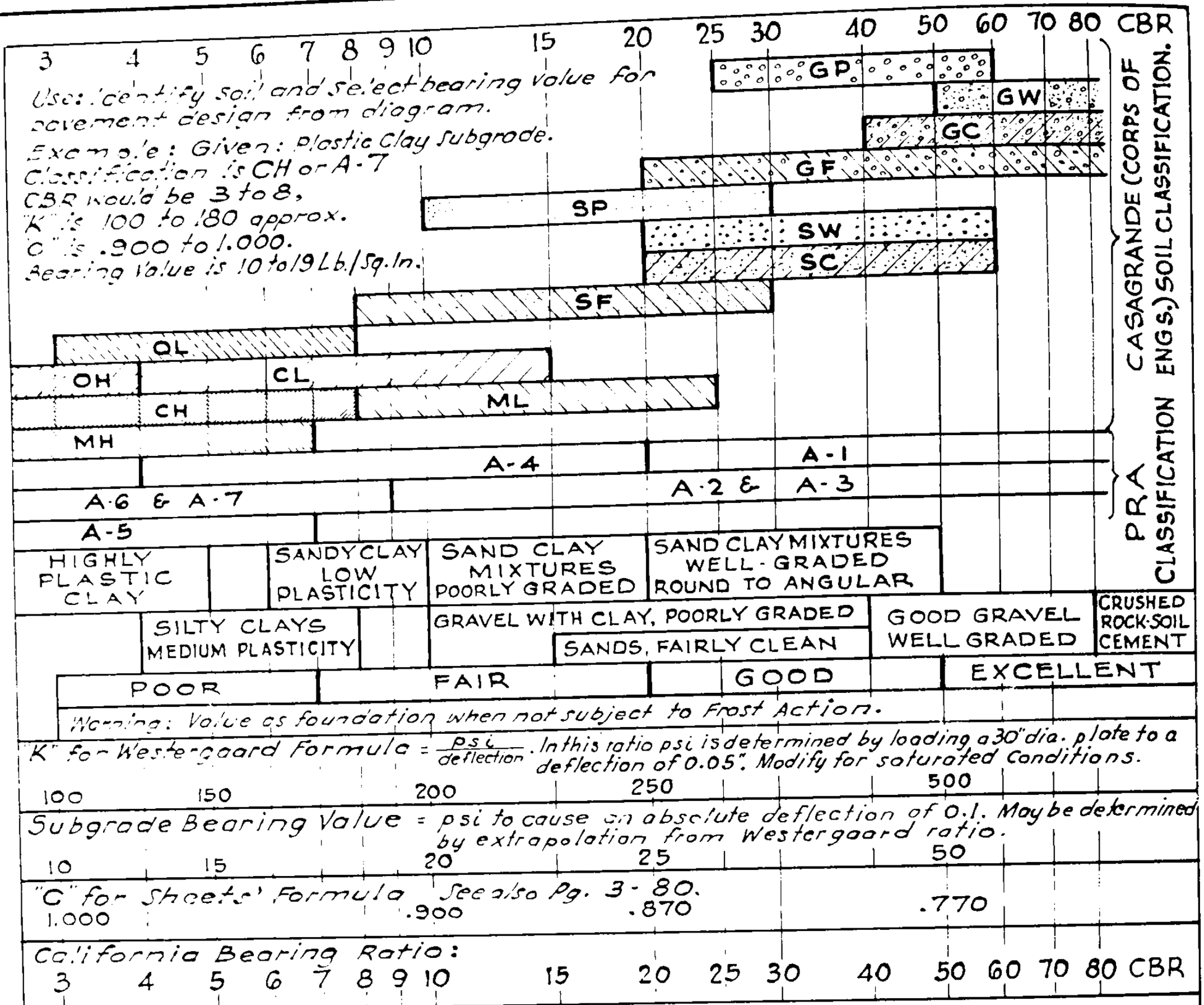


FIG. A- SOIL BEARING VALUE & CLASSIFICATION DIAGRAM.
FOR DESIGN OF HIGHWAY & AIRFIELD PAVEMENT.

LEGEND FOR GROUP SYMBOLS.

C- Clay, Plastic-inorganic Soil.	L- Relatively Low to Med. Compressibility	Pt.- Peat, Highly Org. Fibrous Soil.
F- Fines, Material < 0.1 mm.	M- Mo very fine sand, Silt Rock flour.	S- Sand, Sandy Soil.
G- Gravel, Gravelly Soil.	O- Organic Silt, Silt-Clay or Clay.	W- Well Graded.
H- High Compressibility.	P- Poorly Graded.	

Notes: Bearing values given are approximate and should not be used as a substitute for CBR or Field Load tests.

For Design of Flexible Pavements see Pages 3-72, 3-73 & 3-74 for Roads and Pgs. 4-29 & 4-30 for Airfields. For Design of Rigid Pavements, see Page 3-80 for Roads and Pgs. 4-26, 27, 28 for Airfields. This diagram is compiled from material in following References:

Soil Tests for Design of Runway Pavements by Middlebrooks (U.S.E.D.) & Bertram (A.A.F.).
Proceedings Highway Research Board, December 1942.
Engineering News Record, Volume 130, No 4. Jan. 28, 1943. Design of Airport Runways, Office, Chief of Engineers U.S. Army. Manual No 3, U.S. Navy, Bureau Yards & Docks. Chapter XX, Eng. Manual, War Dept. Conc. Road Design by Frank T. Sheets.

SOILS - SURVEYING & SAMPLING METHODS

SEE ALSO SOILS - SURVEYING & SAMPLING DEVICES - Pg. 3-10.

TABLE A - EXPLORATION & SAMPLING METHODS.*

METHOD	MATERIAL IN WHICH USED	PENETRATION METHOD	SAMPLING METHOD	TYPE OF SAMPLE	PURPOSE OR VALUE
Rod Sounding or Jet Probing	All Soils except Hardpan or Boulders.	Driving 1" Steel Rod or 3/4" jet pipe with hand pump.	No Sample.		To obtain depth of Muck or soft strata. Location Ledge or Boulders. Otherwise Valueless.
Wash Borings		Washing inside 2 1/2" driven casing with chopping bit on end of 1" Ex. heavy pipe.	Sample recovered from sediment in wash water.	Disturbed - edimentary. Coarse grains only.	Depth to Ledge or Boulders Otherwise valueless. Results deceptive & dangerous.
Dry Sample Boring.	"	"	Open end pipe or split spoon sampler driven into soil.	Disturbed but not separated.	Density Data from penetration of spoon. Fairly reliable and inexpensive.
Special Sampling Devices.	Cohesive Soils.	Driven Casing or Auger boring	By special sampling spoon or device.	Undisturbed.	To obtain samples for laboratory study.
Auger Boring.	Cohesive Soils. Cohesionless Soils above ground water	Soil, Wood or Post Hole. Auger rotated by hand or machine & withdrawn.	Sample recovered from Soil brought up by Auger.	Disturbed but better than wash samples.	To locate soil strata & ground water. Roads Air fields, Canals & Railroads. Samples for visual inspection and soil profile.
Well or Churn Drilling.	All soils including Boulders Rock & Gravel.	Churn Drilling by Power.	Bailed sample of churned material or use of "Clay socket".	"Clay Socket" or "Dry" Sample.	Occasionally used for foundations. "Bailed" Samples Worthless.
Rotary Drilling	"	Rotating Bit.	From Circulating liquid.	Fluid Sample.	Samples worthless.
Core Drill Borings	Large Boulders & Solid Rock.	Diamond, Shot or Sawtooth Cutters.	Cores cut & recovered.	Rock Cores 7/8" and over in Dia.	Best method to obtain type & condition of rock.
Test Pits & Caissons.	All soils. Below ground water use pneumatic Caisson or lower water table.	Excav. by hand or Power. Pit over 6' sheeted or lagged.	Bulk sample by hand. Undisturbed sample with spoon, tube or spec. device.	Disturbed or Undisturbed.	Most satisfactory Method. Should supplement others. To obtain undisturbed sample Cohesionless Soil. Soil Can be inspected in natural Condition.
Geophysical Seismic, Elec. Resistance, Elec. Potential.	No samples. Continuous vibration or impulse from dynamite explosion. Device to register vibrations. Mostly patented methods.				Primary exploration. Will indicate earth, loose rock or solid rock. Interpretation uncertain.

TABLE B - SPACING & DEPTH OF BORINGS & TEST PITS OR TEST HOLES.

HIGHWAYS:** At 100' stations plus additional necessary at culverts, bridges, weak zones, wide cuts & fills, muck deposits, borrow pits and sources of base material. Depth not less than 3' below subgrade. Locate ground water table, seepage sources & direction of flow.

AIRFIELDS:** At 100' to 1000' spacing on ℄, edge of pavement & edge of shoulders. Depth not less than 4' to 6' below subgrade in cut or ground surface in fill. Not less than twice diameter of tire contact area nor less than frost penetration. Locate ground water table & seepage data. Make Field Load Bearing Tests at time of survey (from 5 to 10 usual for each Airfield).

BRIDGES, DAMS & PIERS:† Borings spaced as needed to bed rock or well below foundation level. Make borings at least 20' into solid rock. Make one or more borings at each Pier 50' min. into solid rock. Use open pit exploration on land and in shallow water. Make soil bearing tests and Pile loading tests.

BUILDING FOUNDATIONS, TOWERS, CHIMNEYS, ETC.:† Borings spaced not over 50' c. to c. Depth 15' to 20' min. below foundation level. Initial borings to depth = 2 x width loaded area. Core borings into rock greater than minimum design depth of rock required. Supplement borings with test pits, load tests and test piles.

*Adapted from Low Dams by Nat. Resources Comm. based on Harvard Grad. Eng. School pub. #208 by H. A. Mohr.
References ** A.S.T.M. - D.420, C.A.A. Specs., *** P.R.A., U.S.E.D., A.A.F. & C.A.A. † Man. Eng. Practice Nº 8, A.S.C.E.

SOILS - SURVEYING & SAMPLING DEVICES

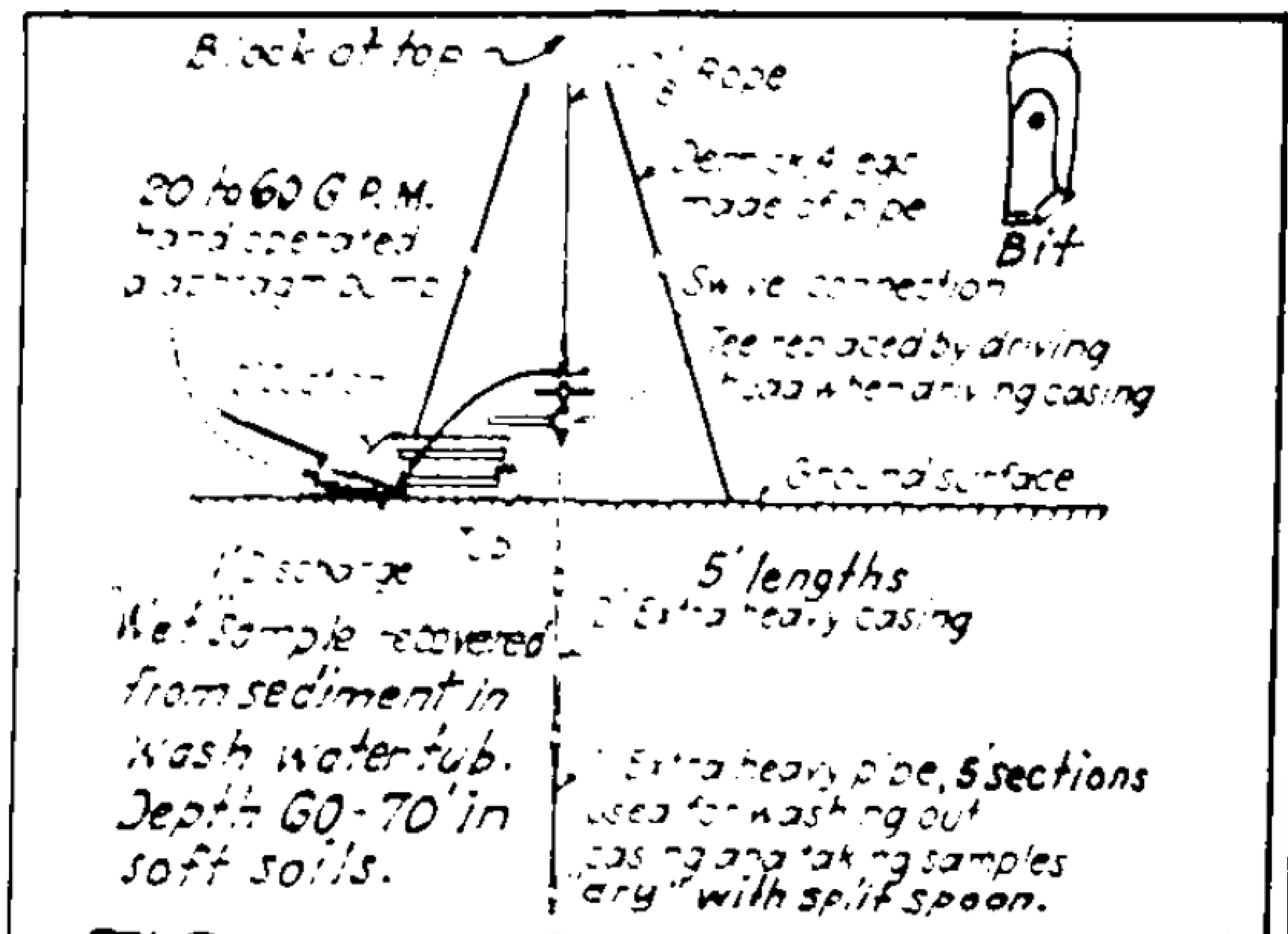
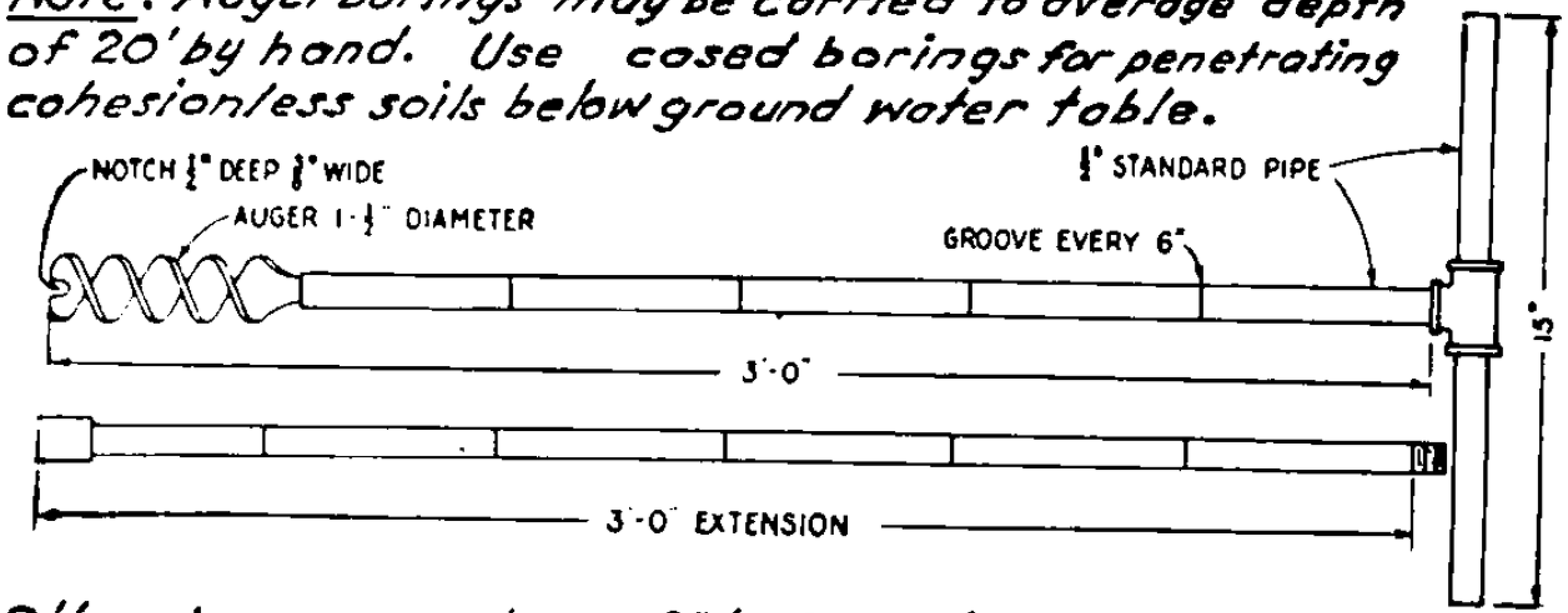


FIG. A - WASH BORING RIG.*

Note: Auger borings may be carried to average depth of 20' by hand. Use cased borings for penetrating cohesionless soils below ground water table.



Other types used are 3" to 8" Post hole augers for sands. 2" to 3" spiral auger for clay soils & muck. Wood augers for hard soils, glacial till, etc. 10" to 20" power driven augers for gravel, etc.

FIG. C - SOIL AUGER*** A.S.T.M. TYPE.

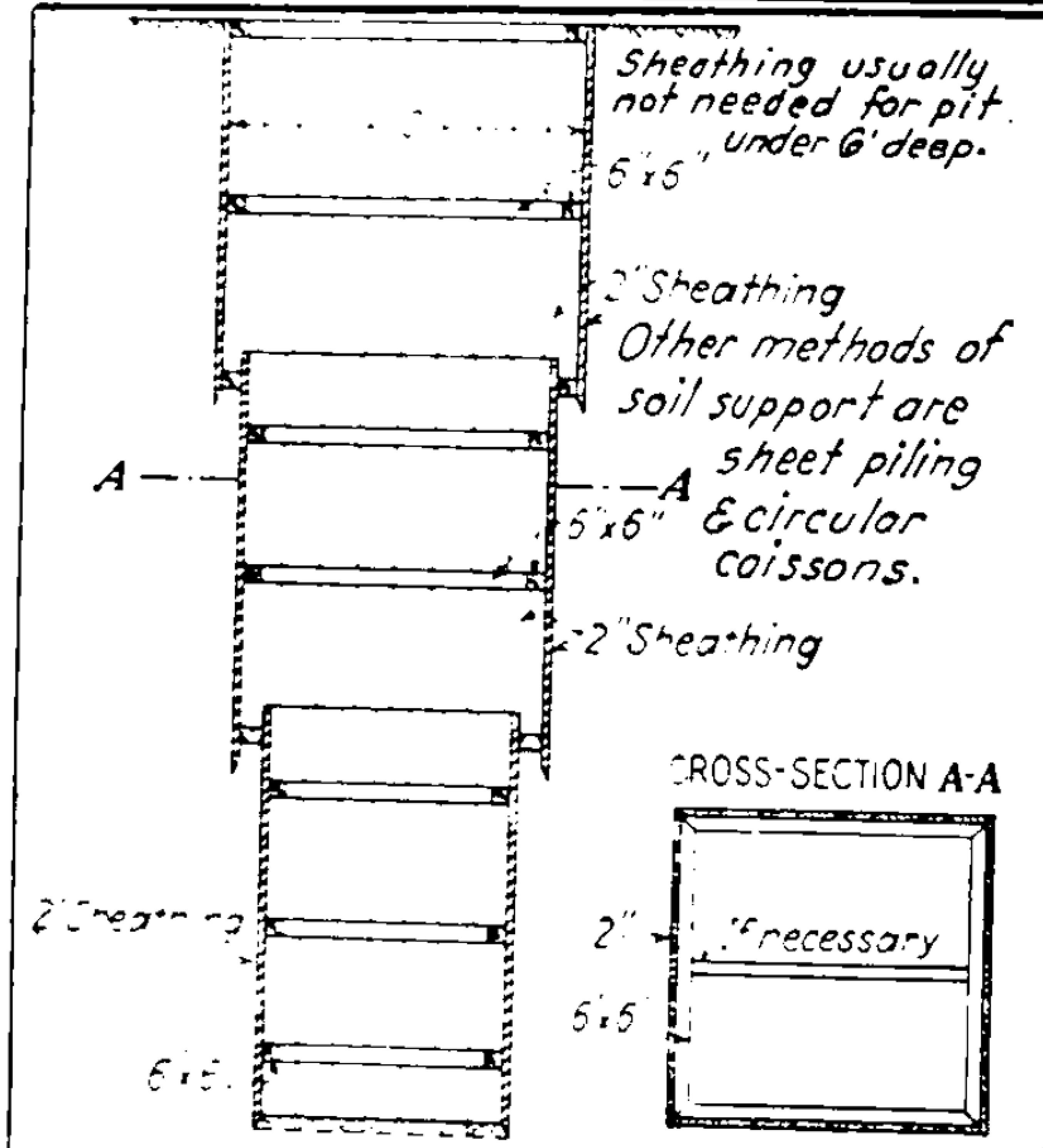
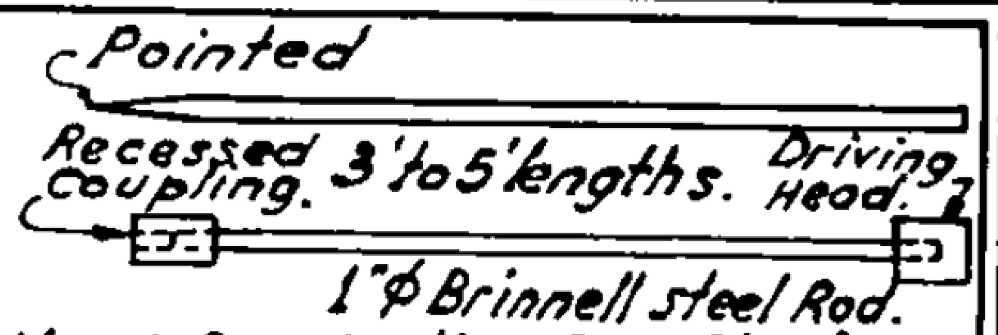
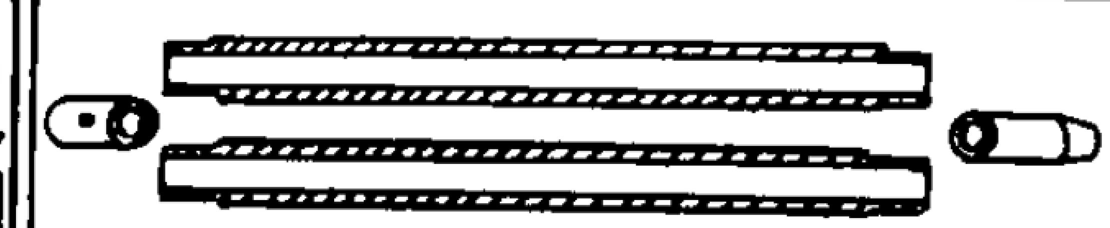


FIG. B - TEST PIT.** SHEATHED & BRACED.



Used for depth of soft soils up to 35' to 40'.

FIG. D - SOUNDING ROD.



For taking "dry" samples with wash boring rig.

FIG. E - SPLIT SPOON SAMPLER.

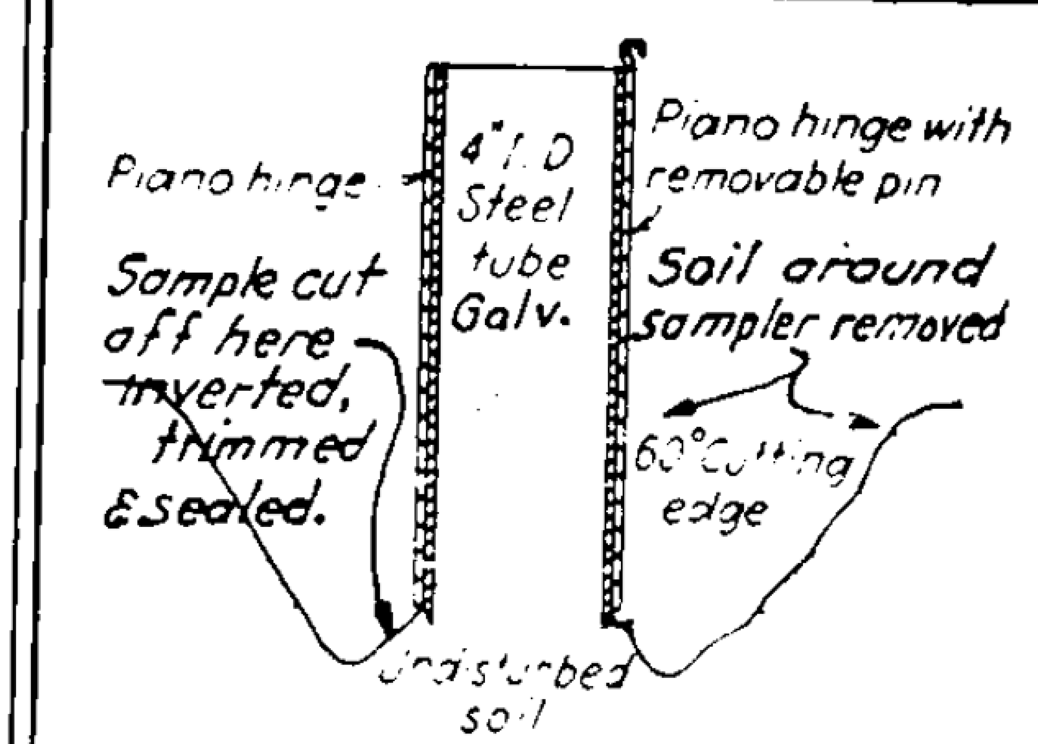
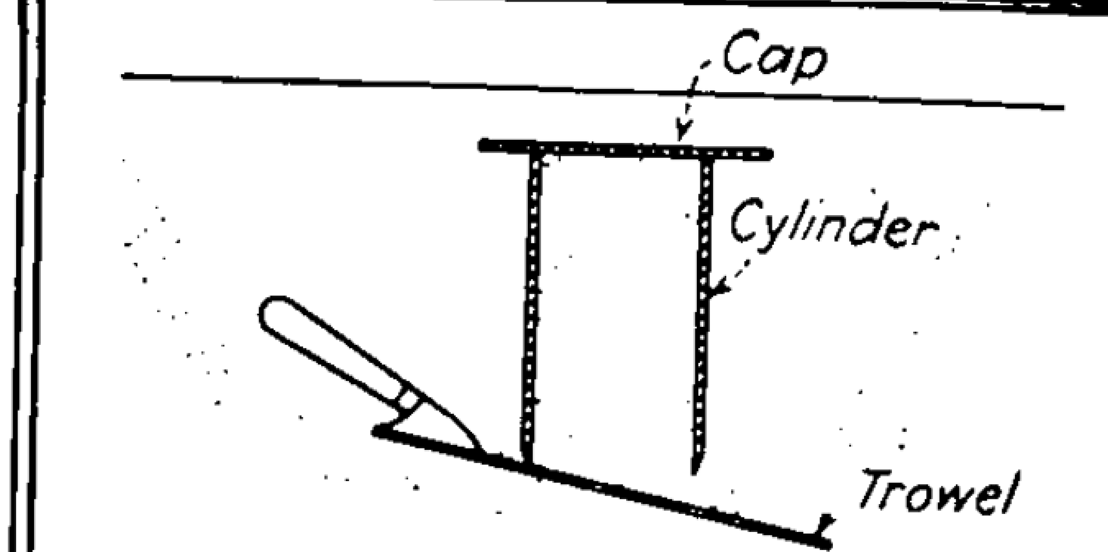


FIG. F - SHALLOW SAMPLER FOR COHESIVE SOIL.****



Cylinder is worked into soil by hand. Sample is reversed, excess soil trimmed and sample sealed.

FIG. G - SHALLOW SAMPLING, COHESIONLESS SOIL (SAND)**

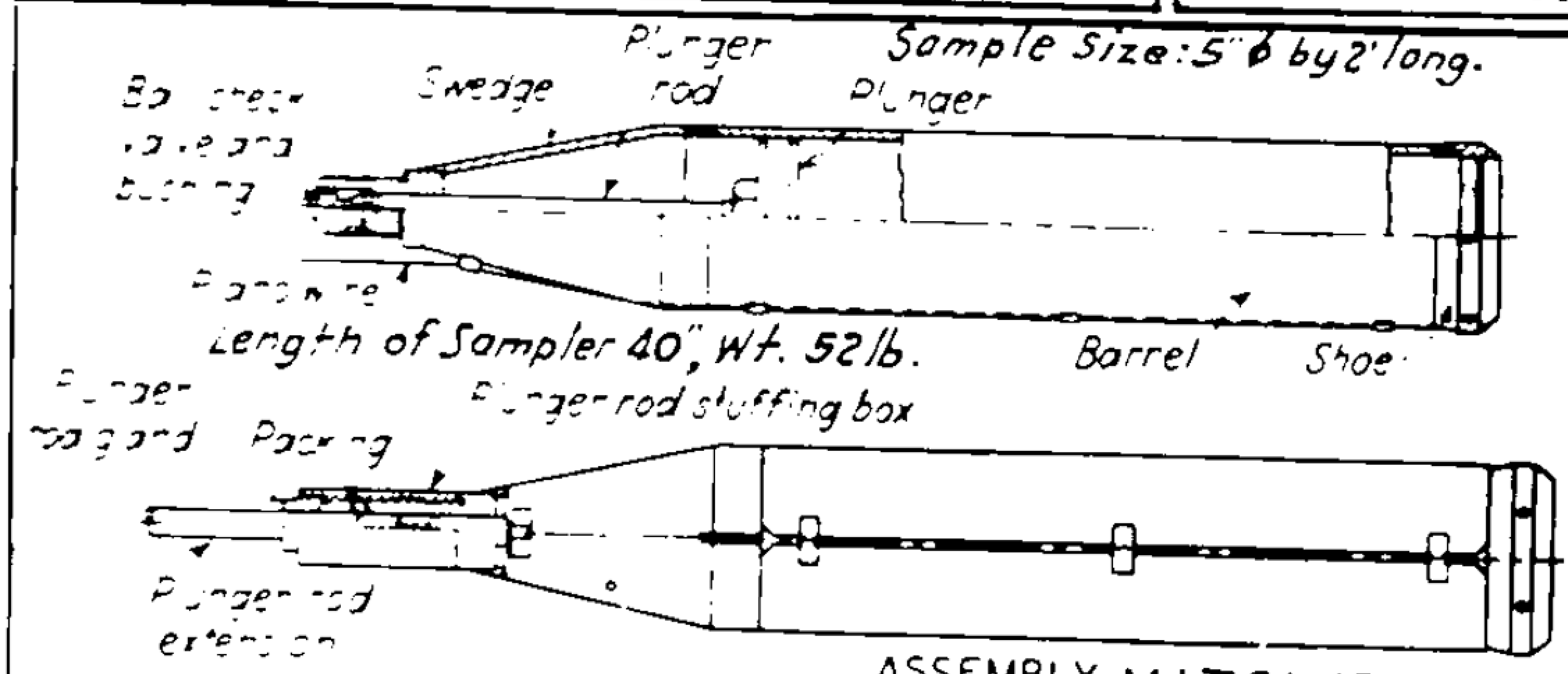
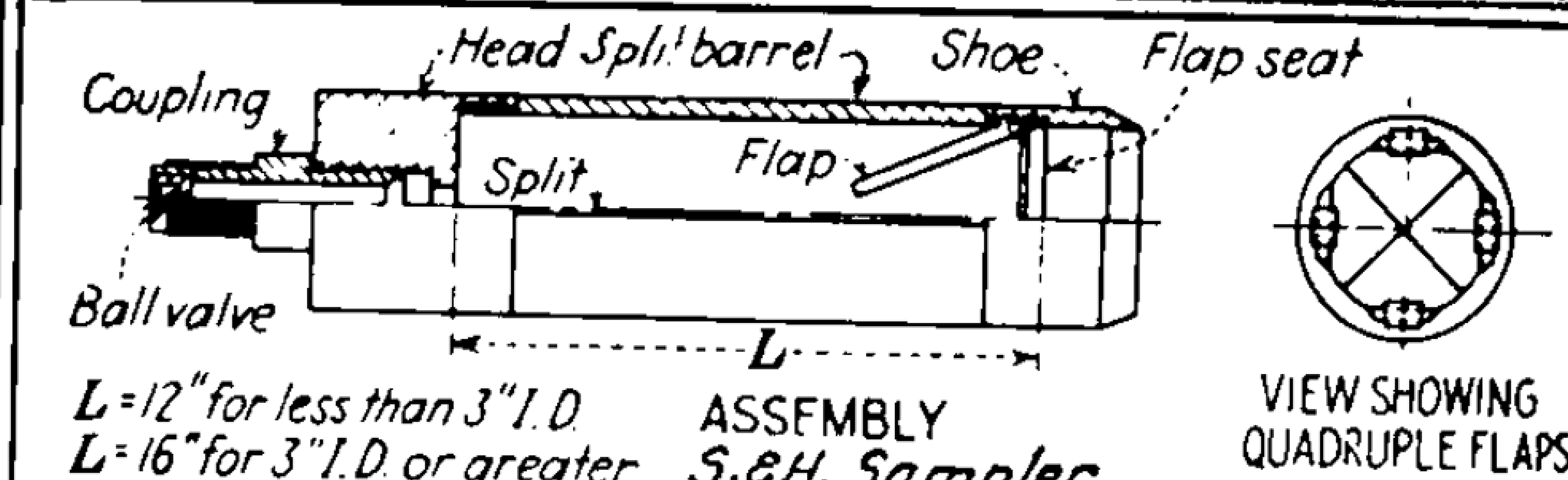


FIG. H - DEEP SAMPLER, COHESIVE SOILS.†



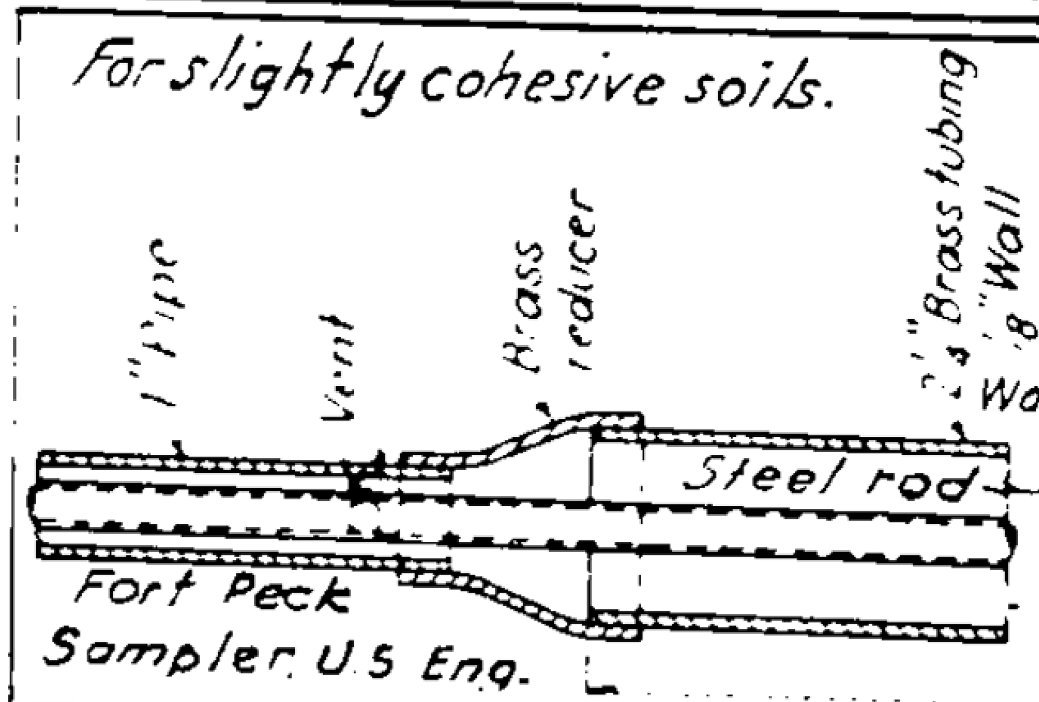
This sampler disturbs soil. Freezing & core drilling have been used with success for undisturbed samples.

FIG. K - DEEP SAMPLER, COHESIONLESS SOIL.**

TABLE L - SIZE OF SAMPLES.	
Visual inspection & record	1 Qt. Mason Jar.
California bearing ratio	125 lbs.
Soil stabilization	125 lbs.
Physical Constants & Mech. Analysis	5-15 lbs.
Aggregates for Construction (Concrete)	35 lbs.
Moisture-Density (Proctor Tests)	10-35 lbs.
Undisturbed Sample	12" to 2' long x 3" to 5" diam.
Rock Core -	Usually 7/8" to 1 1/2" diam.

Note: Seal undisturbed samples in tube with paraffin so structure and moisture content are not disturbed. Place bulk (disturbed) samples in bag or container tight enough so fines will not be lost.

For slightly cohesive soils.

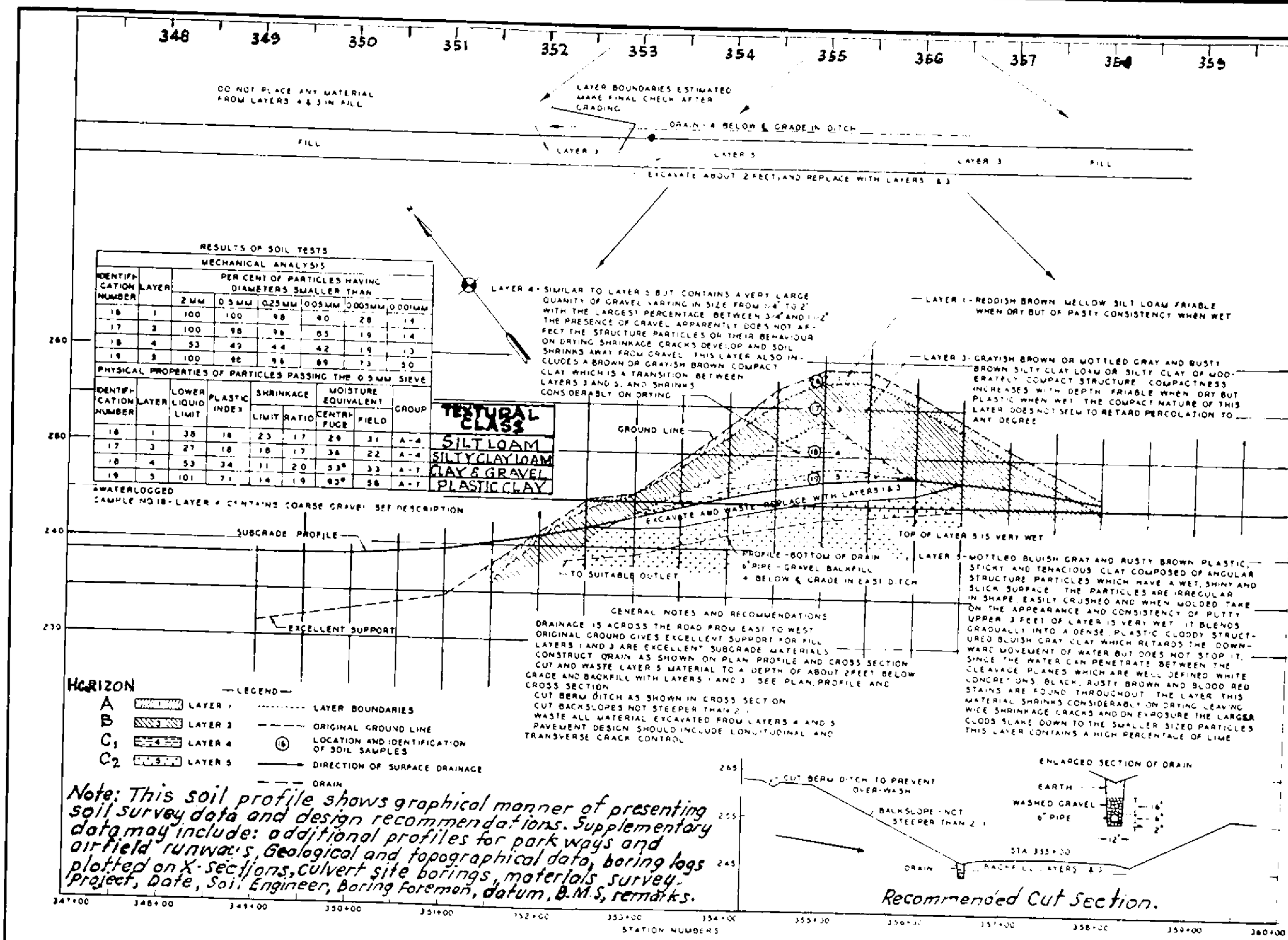


Note: A suggested sampler is the one used by Providence U.S.E.D.; "Clay Sampler Type C" consists of 4 3/4" diam. brass tube 1/16" thick plus a piston.

FIG. I - PISTON TYPE SAMPLER - COHESIVE SOILS.

*After Mohr. ** Krynine, Soil Mech., McGraw-Hill. *** From Humboldt Mfg Co., Chicago **** After Taylor
† From Gilboy & Buchanan Proc. A.S.C.E. Vol. 59, 1933.

SOILS - SOIL PROFILES & BORING LOGS



RESULTS OF SOIL TESTS

IDENTIFICATION NUMBER	LAYER	MECHANICAL ANALYSIS — PER CENT OF PARTICLES HAVING DIAMETERS SMALLER THAN 2 MM	0.5 MM	0.25 MM	0.05 MM	0.005 MM	0.001 MM
16	1	100	100	98	90	28	19
17	3	100	98	96	65	19	14
18	4	53	49	44	42	19	14
19	5	100	98	96	89	73	50

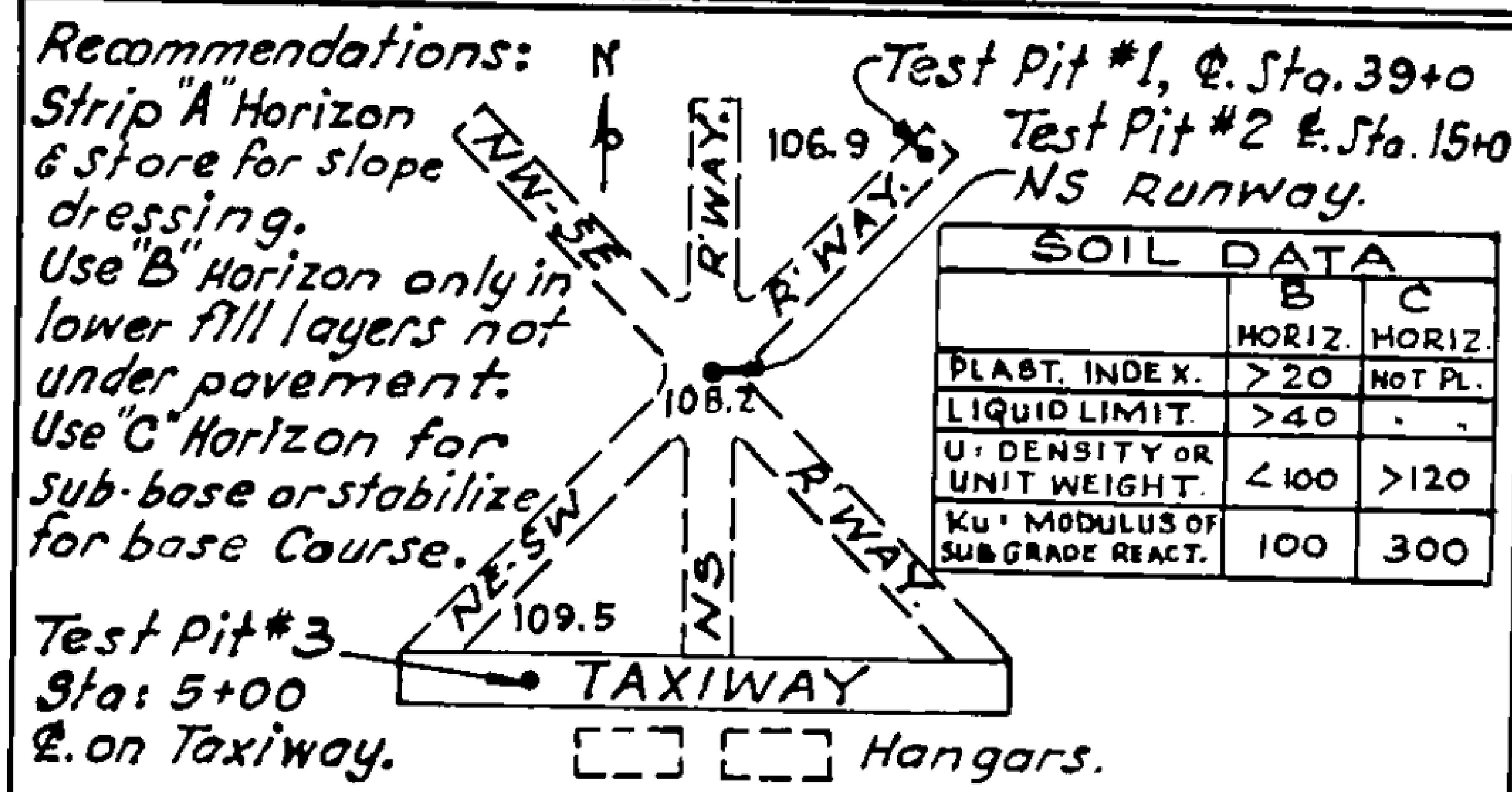
PHYSICAL PROPERTIES OF PARTICLES PASSING THE 0.5 MM SIEVE

IDENTIFICATION NUMBER	LAYER	LOWER LIQUID LIMIT	PLASTIC INDEX	SHRINKAGE LIMIT	SHRINKAGE RATIO	MOISTURE EQUIVALENT CENTRIFUGE	MOISTURE EQUIVALENT FIELD	GROUP	TEXTURAL CLASS
16	1	38	16	23	17	29	31	A-4	SILT LOAM
17	3	27	10	18	17	36	22	A-4	SILTY CLAY LOAM
18	4	53	34	11	20	53*	33	A-7	CLAY & GRAVEL
19	5	101	71	14	19	93*	56	A-7	PLASTIC CLAY

*WATERLOGGED
SAMPLE NO 18 - LAYER 4 CONTAINS COARSE GRAVEL. SEE DESCRIPTION

FIG. A - TYPICAL SOIL PROFILE MAP.†

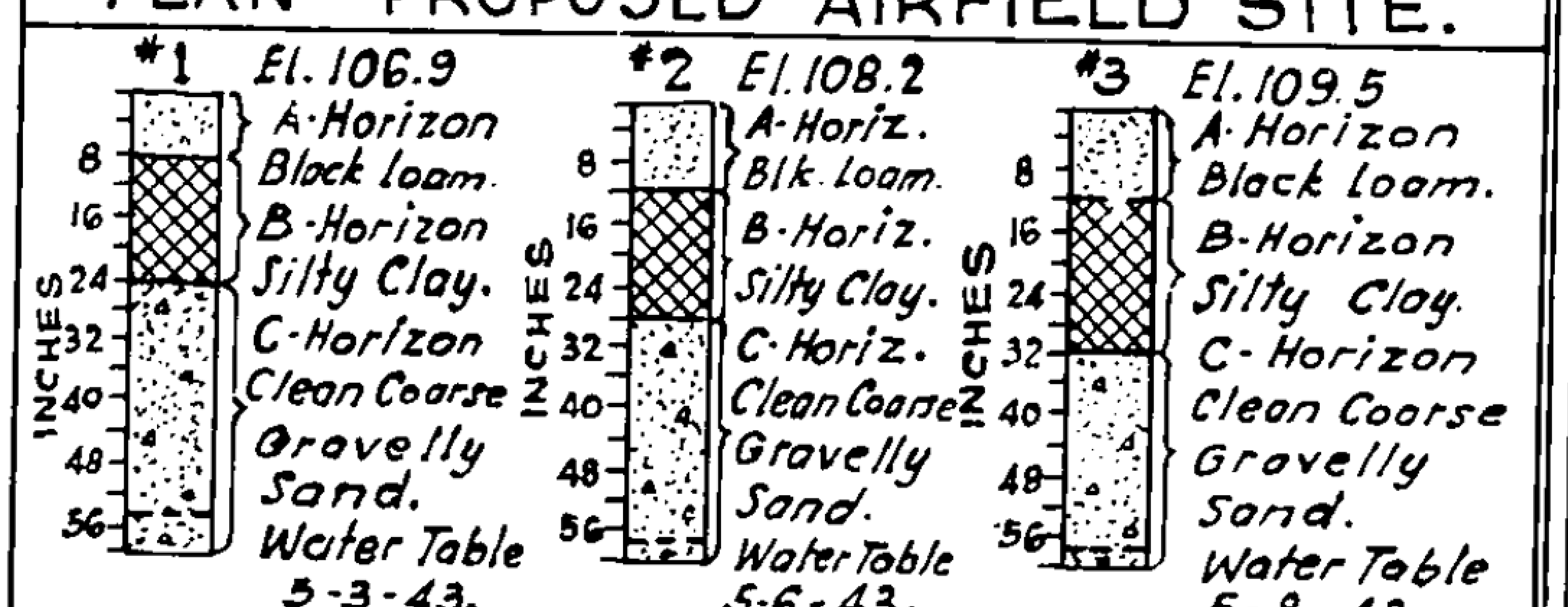
As made for design and construction of Roads, Runways, Railroads and Canals.



SOIL DATA

	B HORIZ.	C HORIZ.
PLAST. INDEX.	>20	NOT PL.
LIQUID LIMIT	>40	-
U: DENSITY OR UNIT WEIGHT	<100	>120
Ku: MODULUS OF SUBGRADE REACT.	100	300

PLAN PROPOSED AIRFIELD SITE.



B-Horiz., A-7, O.L. Low Plasticity CBR #1-6, #2-4, #3 = 8.
C-Horiz., A-3, G.P. Cohesionless, CBR #1-32, #2-55, #3 = 40.

FIG. B - PLAN & LOG OF TEST PITS FOR AIRFIELD.

FIG. C - TYPICAL BORING LOG †† STRUCTURES.

LOCATION ANTIGUA ..... STRUCTURE HANGAR (See key Plan) SHEET No. 1 OF 2
BORING No. 1 DATUM ..... BORING INSPECTOR SMITH DATE 1-3-41.

MISCELLANEOUS DATA
- LENGTH OF HOLE 26'0
- ROCK 5'0"
- WT OF HAMMER 300 lbs
- AVER FALL OF HAM. 30"
- EL. OF GRD WATER +68.4

STRATIFICATION ELEVATION	DEPTH	LEGEND	DESCRIPTION OF MATERIALS (TYPE COLOR & CONSISTENCY)	CASING BLOWS	CASING PENETRATION	SAMPLER OR SPOON BLOWS	SAMPLER OR SPOON PENETRATION	* SAMPLE NO	REMARKS**
73.7	0		Surface						
			Brown Sandy Loam						Few Roots
			Trace of Gravel.			6	12	1D	Dry & Friable
71.2	2'6"								
				8	12"	32	18"	2D	Fairly Firm.
			Fine Brown Sand	10	12"				Cohesionless.
66'	G.W.		Trace of Gravel.	16	12"				Resistance
				16	12"	28	12"	3D	Increases with depth.
64.7	9'0"								
			Firm, Hard Yellow,						Becomes Plastic
62.2	11'6"		Silty Clay.	18	12	20	18"	4D	when worked.
			Compact Gravel.	380	12"	60	3"	5D	Chips of black slate
52.7	21'0"		Silt & Sand Hardpan						embedded in silt.
			Buff-colored						Casing & Rods
			Limestone.					6C	Refused at 21'-0"
			Hard 80% core						Bottom of Hole
47.7	26'0"		recovery.						at 26'-0".

Note: Additional data may include: Key plan with contours, stations coordinates and building outline; Benchmarks, date, drilling rig, casing dia.; Atterberg limits, Mech. Analysis, density, water content.

* WRITE SAMPLE NO AT CORRESPONDING DEPTH. DESIGNATE DRY SAMPLES BY D, WASH SAMPLES BY W, UNDISTURBED SAMPLES BY U, ROCK CORES BY C

** WHEN DRILLING CORES IN ROCK RECORD THE PERCENTAGE OF RECOVERY IN EACH FOOT OF PENETRATION

Adapted from: † Surveying & Sampling Soils for Highway Subgrades, A.S.T.M. †† Caribbean Architect - Engineer

SOILS - ATTERBERG LIMIT TESTS

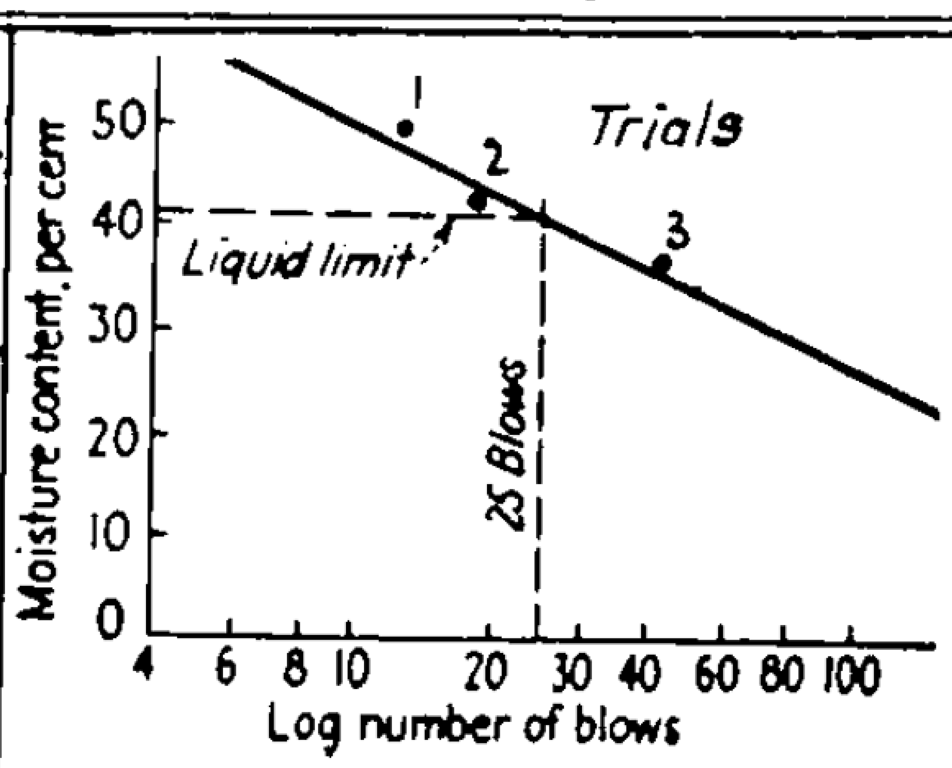
PURPOSE:

1. To classify soils into P.R.A. or Casagrande Groups.
2. To assign soils a value as a foundation or construction material.
3. Construction control and laboratory reports. High values of L.L. and P.I. indicate high compressibility and low bearing capacity. High shrinkage values indicate excessive volume change.

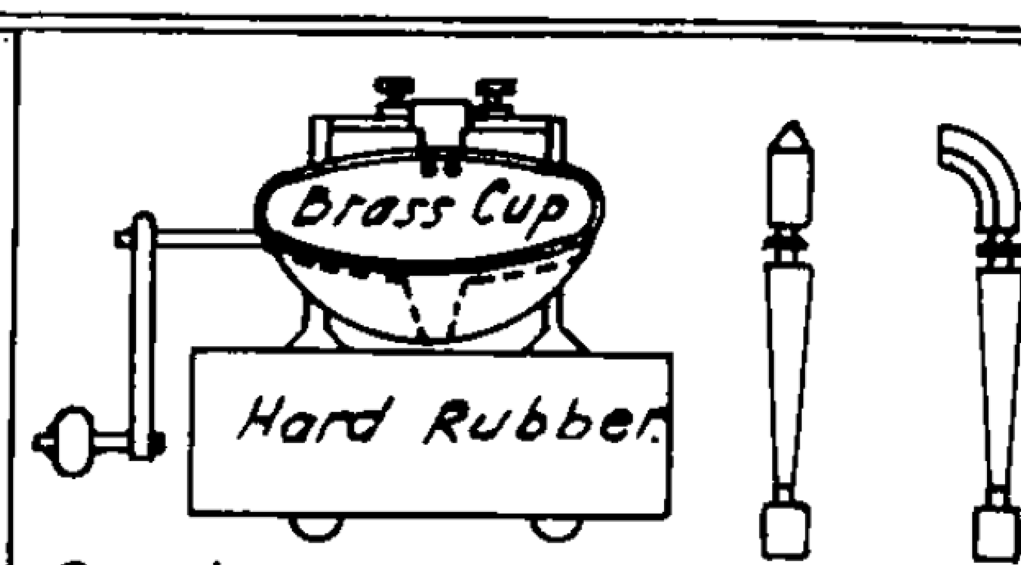
TABLE A-LIMITING VALUES	BASE COURSE	SUBGRADE	SUB-BASE	STAB. SURF.	SOIL CEMENT	CEM. TREATED BASE
	No Shrinkage L.L.=25; P.I.=6 max	Lineal Shrinkage 3% to 5%	L.L.=35; P.I.=15 max.	P.I.=4 to 9	L.L.=40; P.I.=18 max.	L.L.=25 P.I.=6 to 9

The water-content or moisture content is expressed as a percentage of the oven dried weight of the soil sample. These soil constants are determined from the soil fraction passing the № 40 (420 micron) sieve.

The Liquid Limit (L.L.) of a soil is the water content at which the groove formed in a soil sample with a Std. grooving tool will just meet when the dish is held in one hand & tapped lightly 10 blows with the heel of the other hand. In the machine method the L.L. is the water content when the soil sample flows together for ½" along the groove with 25 shakes of the machine at 2 drops per sec. Diameter of brass cup or evaporating dish about 4½".



EXAMPLE OF FLOW CURVE*



CASAGRANDE LIQUID LIMIT MACHINE

‡

Size of sample: By hand 30 grams: By machine 100 grams. Several trials are made, the moisture content being gradually increased. Blows are plotted against water content and the Liquid Limit picked off from the curve as shown

$$\text{or } L.L. = \frac{\text{Weight of water}}{\text{weight of oven dried soil}} \times 100.$$

FIG. B - LIQUID LIMIT (L.L.) A.S.T.M. D 423, A.A.S.H.O., T-89.

The Plastic Limit (P.L.) is the lowest water content at which a thread of the soil can be just rolled to a diam. of ⅛" without cracking, crumbling or breaking into pieces.

$$P.L. = \frac{\text{Weight of water}}{\text{Wt. of oven dried soil}} \times 100$$

Size of soil sample is 15 grams. Soil which cannot be rolled into a thread is recorded as Non-Plastic (N.P.)

SOIL THREAD ABOVE THE PLASTIC LIMIT.

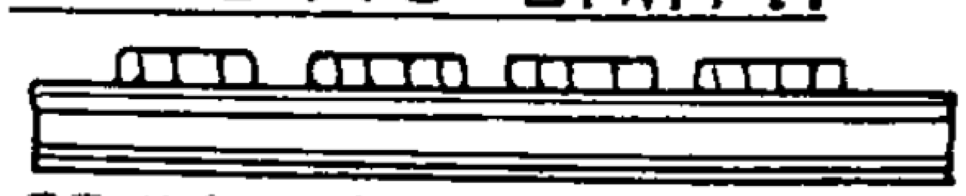

CRUMBLING OF SOIL THREAD BELOW THE PLASTIC LIMIT.

FIG. C - PLASTIC LIMIT (P.L.) A.S.T.M. D 424, A.A.S.H.O., T-90.

PLASTICITY INDEX (P.I.): A.A.S.H.O., T-91. numerical difference between LIQUID LIMIT (L.L.) & PLASTIC LIMIT (P.L.) or P.I. = L.L. - P.L. Example: Given L.L. = 28, P.L. = 24, P.I. = 4 Cohesionless soils are reported as Non-Plastic (N.P.). When Plastic Limit is equal to or greater than Liquid Limit the P.I. is reported as 0. See Table A, Pg. 3-03.

SHRINKAGE RATIO (R): = bulk specific gravity of the dried soil pat used in obtaining Shrinkage Limit.

$$R = \frac{\text{Weight of oven-dried soil pat in grams}}{\text{Volume of oven dried soil pat in c.c.}} \text{ or } \frac{W_o}{V_o}$$

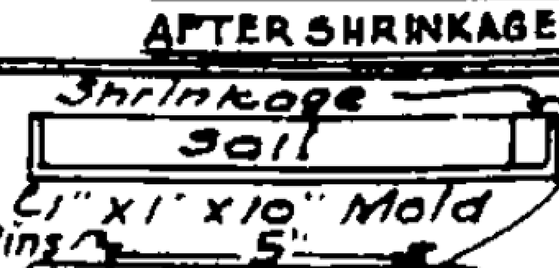
SHRINKAGE LIMIT (S): A.S.T.M., A.A.S.H.O. T-92. Water content at which there is no further decrease in Volume with additional drying of the soil but at which an increase in water content will cause an increase in volume.

$$S = \left(\frac{1}{\text{Shrinkage Ratio}} - \frac{1}{\text{Spec. Gravity}}\right) \times 100.$$

Size of sample 30 grams. 1¾" Dia. x ½" High Milkdish.

LINEAL SHRINKAGE: is the decrease in one dimension of the soil mass when the water content is reduced to the Shrinkage Limit or the % change in length occurring when a moist sample has dried out.

FIELD TESTS.



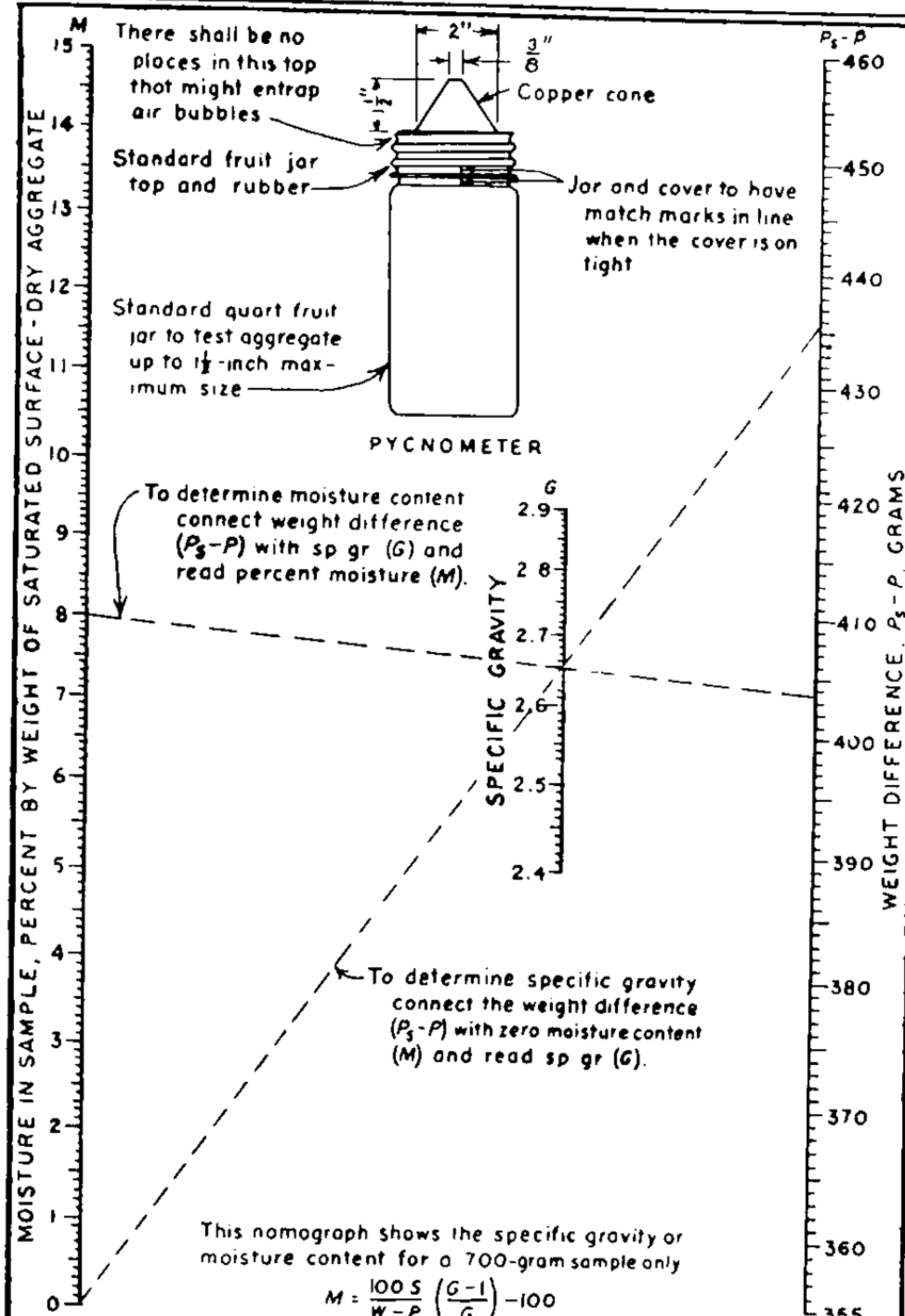
Adapted from *Krynine, Soil Mechanics, McGraw-Hill. ‡ Hogentogler, Engineering Properties of Soil, McGraw-Hill.

SOILS - MOISTURE DETERMINATION

PURPOSE: 1. To determine moisture content for optimum moisture and maximum density relations.

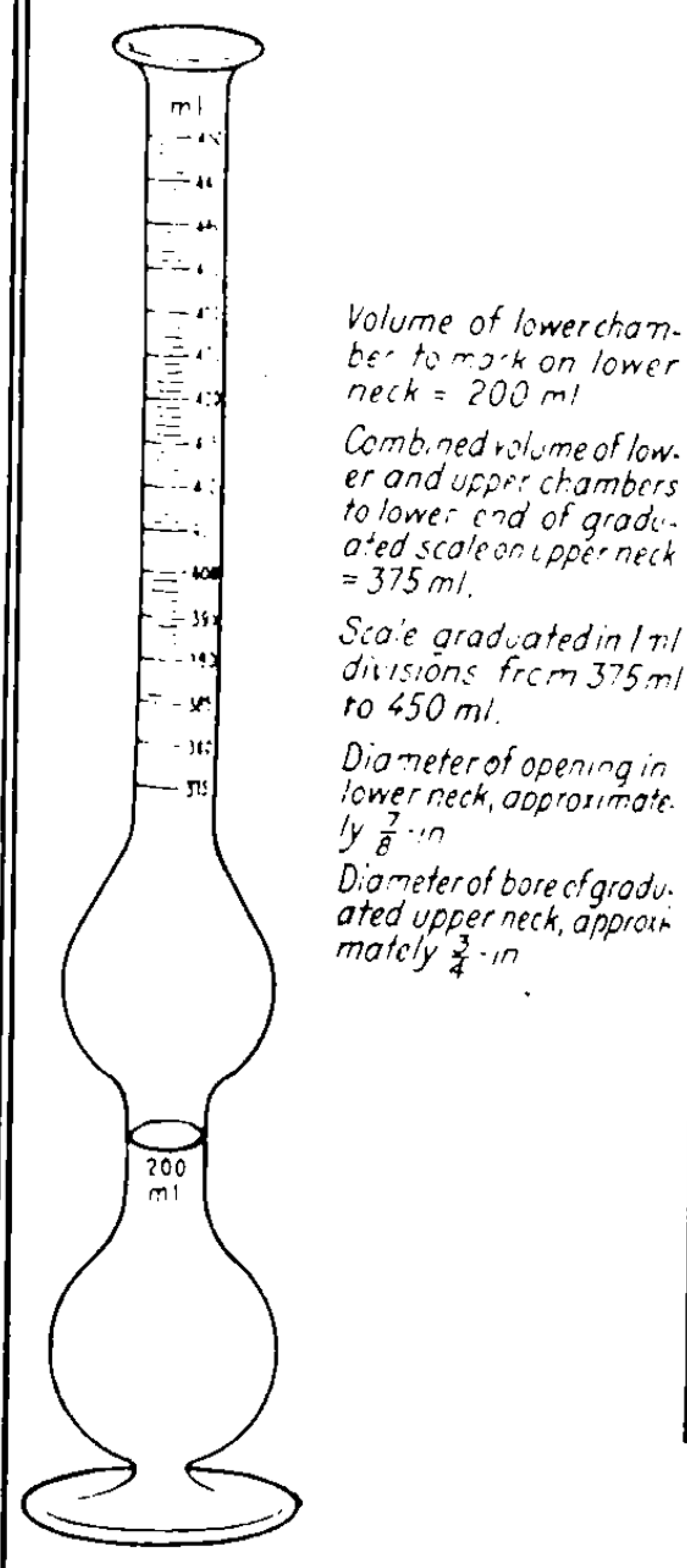
2. To determine the amount of water in aggregates for concrete, bituminous and other mixtures.

Gravelly Soils: Use Pycnometer Method - Fig. A or heat method described below.
Sandy Soils : Use Chapman Flask - Fig. B or heat method described below.
Silts and Clays: Use heat method described below.



M, moisture in sample, percent by wt of saturated surface-dry aggregate
S, weight of moist-sand sample = 700 g for use with this nomograph
P, weight of the pycnometer full of water, grams
P_s, weight of the pycnometer containing the sample and filled with water, grams
G, specific gravity of the aggregate, saturated and surface-dry

FIG. A - SPECIFIC GRAVITY & SURFACE MOISTURE CONTENT OF AGGREGATE - PYCNOMETER METHOD.



USE OF THE CHAPMAN FLASK:

Fill to the 200 milliliter mark on the lower neck with water. Add 500 grams of moist soil and read the combined volume = V on upper scale. M = approximate percentage of surface moisture.

$$M = \frac{V - \frac{500}{Sp.Gr.} - 200}{200 + 500 - V} \times 100 .$$

Sp. Gr. = The bulk specific gravity of the surface dry aggregate found by the equation $500 \div (V' - 200)$.

V' differs from V in that 500 grams of dry sample is added instead of 500 grams of a moist sample as in the case of V. This method is only practical for the surface moisture of relatively sandy soils.

Use stirring rod to eliminate air.

CHAPMAN FLASK*

NOTE: Use with caution on account of absorbed air present.

FIG. B - SPECIFIC GRAVITY & SURFACE MOISTURE CONTENT OF AGGREGATE - CHAPMAN FLASK METHOD.

HEAT METHOD: FOR TOTAL MOISTURE CONTENT OR SURFACE MOISTURE CONTENT.

1. Obtain a representative sample. If a metric scale is available the sample should not be smaller than 100 grams. If an avoirdupois scale graduated by 1/2 ounces is used, the sample should contain at least 50 ounces.
2. Weigh sample and record weight.
3. Place sample in pan and spread to permit uniform drying. Set pan in oven or on top of stove in a second pan to prevent burning of soil.
4. Dry to constant weight when total moisture is to be found; dry until surface moisture disappears when surface moisture content is desired. Temperature should not exceed 105°C (221°F). Stir constantly to prevent burning.
5. After the sample has been dried to constant weight, remove from oven and allow to cool sufficiently to permit absorption of hygroscopic moisture. Weigh dried sample and record weight.
6. Compute the moisture content as follows:

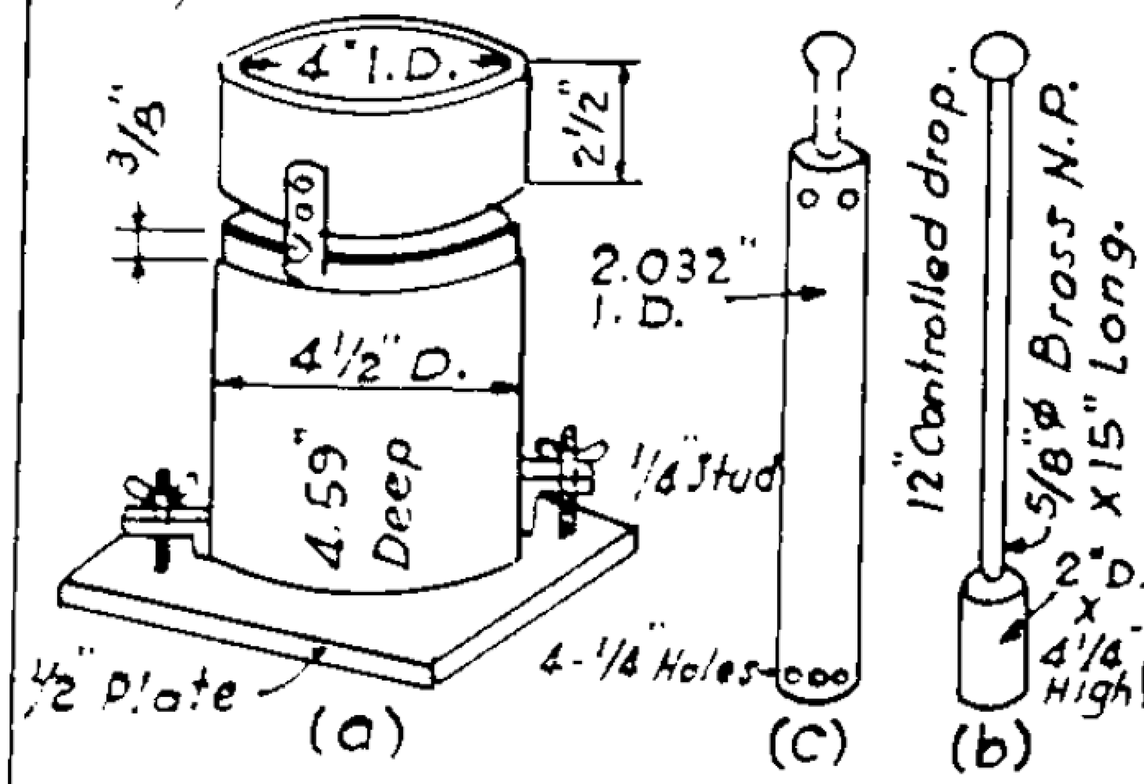
$$\text{Percent Moisture} = \frac{\text{weight of wet soil} - \text{weight of dry soil}}{\text{weight of dry soil}} \times 100.$$

*From A.S.T.M. Specifications.

SOILS – {MAXIMUM DENSITY / OPTIMUM MOISTURE} – {PROCTOR NEEDLE / PLASTICITY TEST}

PURPOSE: of Maximum Density - Optimum Moisture is to determine the % of moisture at which the Maximum Density can be obtained when soil is compacted in fill, earth dams, embankments, etc.
Purpose of the Proctor Needle test is to obtain a measure of the degree of compaction of a soil by measuring its resistance to penetration. Also a method of determining soil moisture. Cannot be used in soils with coarse particles. Used mostly in earth dam construction.

MAX. DENSITY - OPTIMUM MOISTURE.
as per A.S.T.M.-D.698 - A.A.S.H.O.-D:T.99.



(a) Mold 1/30 Cu.ft.
(b) Rammer
(c) Sleeve
(d) Balance or Scale 25# cap. Sen. to 0.01#
(e) Balance 100 g sensitive to 0.1 g
(f) Drying oven 110 C. or 230 F.
(g) 12" Straightedge.

APPARATUS NEEDED.

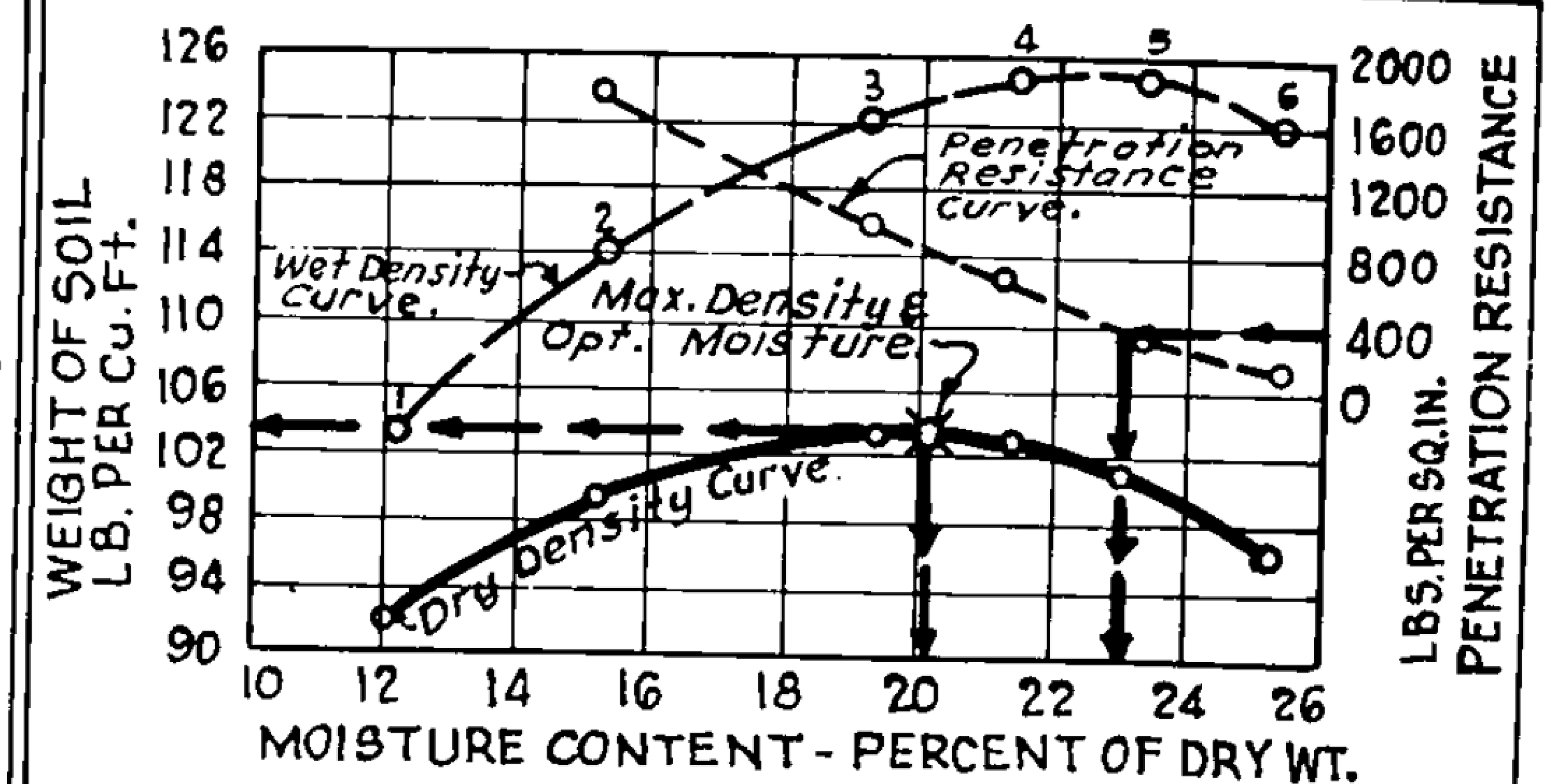


FIG. B - MOISTURE-DENSITY PENET. CURVES.

TESTING PROCEDURE:

6 lb. ± (3000 grams) of air dried soil slightly damp & passing the No. 4 sieve is mixed thoroughly, then compacted in the mold of 1/30 of Cu.ft. capacity in 3 equal layers. Each layer receiving 25 blows from the rammer with a Controlled drop of 1 ft. The collar is removed and the soil struck off level and weighed.

(Wt. of soil plus mold – wt. of mold) x 30 = wet weight per cubic foot or wet density.

A 100 g. sample from the center of the mass is weighed, dried at 230 F. and moisture content determined.

Pulverize original 6 lb., add about 1% water and repeat test. Repeat until soil becomes saturated (about 5 times). Plot Wet-Density Curve. See Fig. B. Compute Dry Density by formula and plot curve:

$$\text{Dry Density} = \frac{\text{Wet Wt.. lb. per Cu. ft.}}{\%\ \text{moisture} + 100} \times 100$$

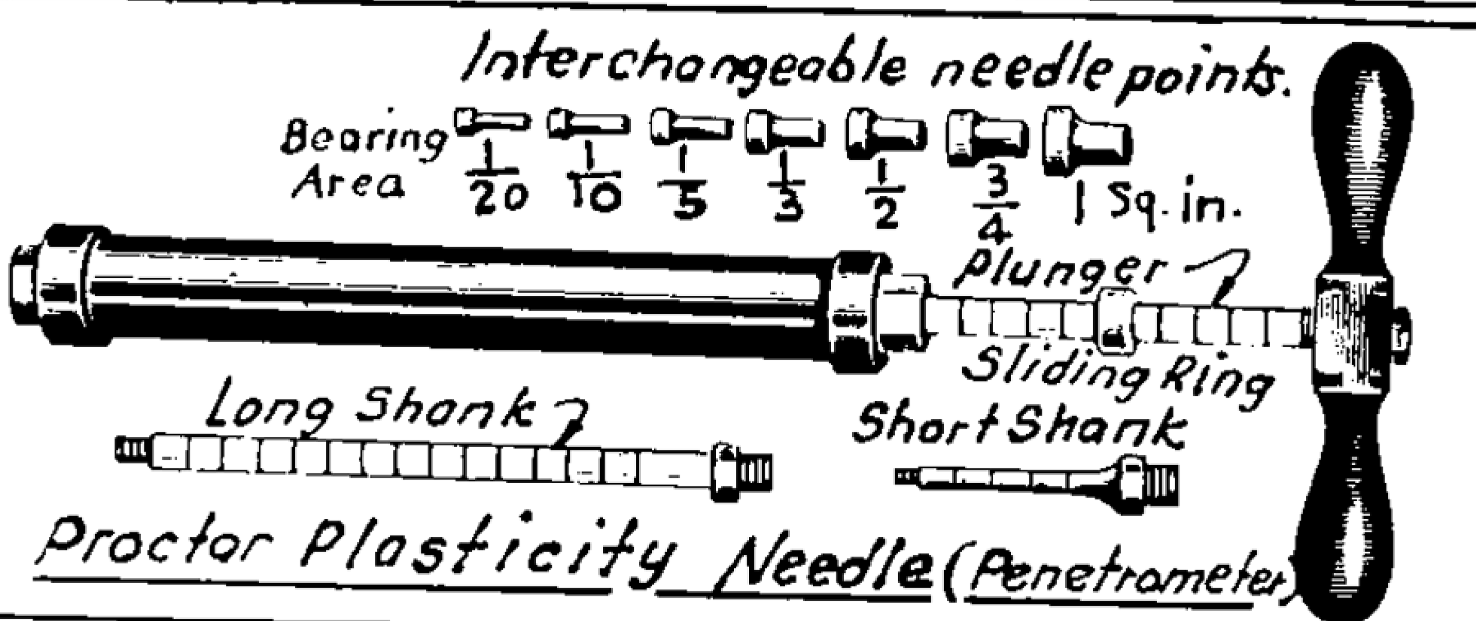
In Fig. B - Enter at top of Dry Density Curve & read optimum moisture & max. wt. of soil 20.2% & 103.5 lb.

MODIFIED A.A.S.H.O. METHOD.**

Same as above except:
1. Rammer to weigh 10 lb.
2. Rammer to have controlled drop of 18".
3. Soil compacted in mold in 5 equal layers 25 blows to each layer.

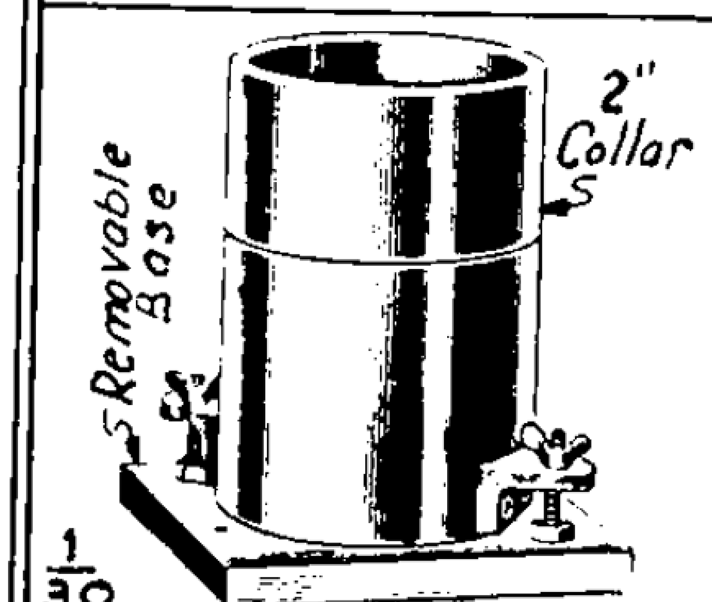
The highest dry density is recorded as Lab. unit Wt.

NOTE: Modern Air-field compaction equipment can secure greater densities than can be obtained by the standard Proctor or A.A.S.H.O. Test. If field compaction or vibration will give greater densities on any job than the test, the higher density should be used to control compaction.



Proctor Plasticity Needle (Penetrometer)

Needle shanks are graduated at ½" intervals to indicate penetration. Plunger rod calibrated for every 10 lb. up to 110 lb. pressure. Ring indicates max. pressure.



1/30 Cu.ft. MOLD
4" I.D. x 4½" Deep.

5½ lb. Rammer
With end area of 3 Sq. Inches.

FIG. C - APPARATUS.*

PROCTOR TEST:† 5 lb. of dry soil passing a No. 10 sieve is mixed thoroughly with just enough water to make it slightly damp, then compacted in the mold in 3 layers. Each layer is given 25 blows with the rammer dropped 1 ft. The soil is then struck off level with the cylinder, weighed, and the stability determined with the plasticity needle by measuring the force required to press it into the soil at the rate of ½" per sec. A small portion of the soil is oven dried to determine the moisture content. This procedure is repeated 3 to 6 or more times, each time adding about 1% more water until the soil becomes very wet. The density & plasticity needle readings are plotted against moisture content; see Fig. B.
Thus in Fig. B a needle reading of 400 gives a moisture content of 23%.

* Adapted from Humboldt Mfg. Co., ** Engineering Manual, O.C.E., War Dept.,
† Engineering News Record. Aug. 31 to Sept. 28, 1933, R. R. Proctor.

SOILS - FIELD DENSITY (UNIT WEIGHT) TEST

PURPOSE: 1. *To obtain the natural density of soil in place (a) as an indication of its stability or bearing value as foundation, (b) to compute the shrinkage or swell when the soil is removed and placed in embankment at a higher or lower density. 2. To determine the per cent of compaction being obtained to check against requirements of specifications.*

METHOD OF DETERMINING WEIGHT PER CUBIC FT. OF SOIL IN PLACE.

CALIBRATED SAND METHOD.

The density of a soil layer may be determined by finding the weight of a disturbed sample and measuring the volume of the space occupied by the sample prior to removal. This volume may be measured by filling the space with a weighed quantity of a medium of predetermined weight per unit volume. Sand, heavy lubricating oil or water in a thin rubber sack may be used.

1. Determine the weight per cubic foot of the dry sand by filling a measure of known volume. The height and diameter of the measure should be approximately equal and its volume should be not less than 0.1 cu. ft. The sand should be deposited in the measure by pouring through a funnel or from a measure with a funnel spout from a fixed height. The measure is filled until the sand overflows and the excess is struck off with a straightedge. The weight of the sand in the measure is determined and the weight per cubic foot computed and recorded.

2. Remove all loose soil from an area large enough to place a box similar to the one shown in Figure B and cut a plane surface for bedding the box firmly. A dish pan with a circular hole in the bottom may be used.

3. With a soil auger or other cutting tools bore a hole the full depth of the compacted lift.

4. Place in pans all soil removed, including any spillage caught in the box. Remove all loose particles from the hole with a small can or spoon. Extreme care should be taken not to lose any soil.

5. Weigh all soil taken from the hole and record weight.

6. Mix sample thoroughly and take sample for water determination.

7. Weigh a volume of sand in excess of that required to fill the test hole and record weight.

8. Deposit sand in test hole by means of a funnel or from a measure as illustrated in **Figure B** by exactly the same procedure as was used in determination of unit weight of sand until the hole is filled almost flush with original ground surface. Bring the sand to the level of the base course by adding the last increments with a small can or trowel and testing with a straightedge.

9. Weigh remaining sand and record weight.

10. Determine moisture content of soil samples in percentage of dry weight of sample.

11. Compute dry density from the following formulas:

$$\text{Vol. Soil} = \frac{\text{Wt. of sand to replace soil}}{\text{Wt. per Cu. ft. of sand.}}$$

$$\%\text{ moisture} = \frac{\text{Wt. moist soil} - \text{Wt. dry soil}}{\text{Wt. of dry soil}} \times 100$$

$$\text{Moist density} = \frac{\text{Weight of soil}}{\text{Volume of soil.}}$$

$$\text{Dry density} = \frac{\text{Moist density}}{1 + \frac{\%\text{ of moisture}}{100}}$$

$$\%\text{ Compaction} = \frac{\text{Dry density}}{\text{Maximum density}} \times 100$$

EXAMPLE: Given:

Wt. per Cubic ft. of sand	= 100 Lb.
Wt. of moist soil from hole	= 5.7 Lb.
Moisture content of soil	= 15%
Wt. of sand to fill hole	= 4.5 Lb.

Required: Density & % Compaction.

Solution: $\text{Vol. Soil} = \frac{4.5}{100} = 0.045 \text{ Cu. ft.}$

$$\text{Moist density} = \frac{5.7}{0.045} = 126.7 \text{ Lbs.}$$

$$\text{Dry density} = \frac{126.7}{1 + 15/100} = 110.0 \text{ Lbs.}$$

Given Maximum density = 115 lbs (from density test Pg. 3-14).

$$\%\text{ Compaction} = \frac{110}{115} \times 100 = 95.7\%$$

Note: In gravel soils material over 1/4" is screened out and correction made.

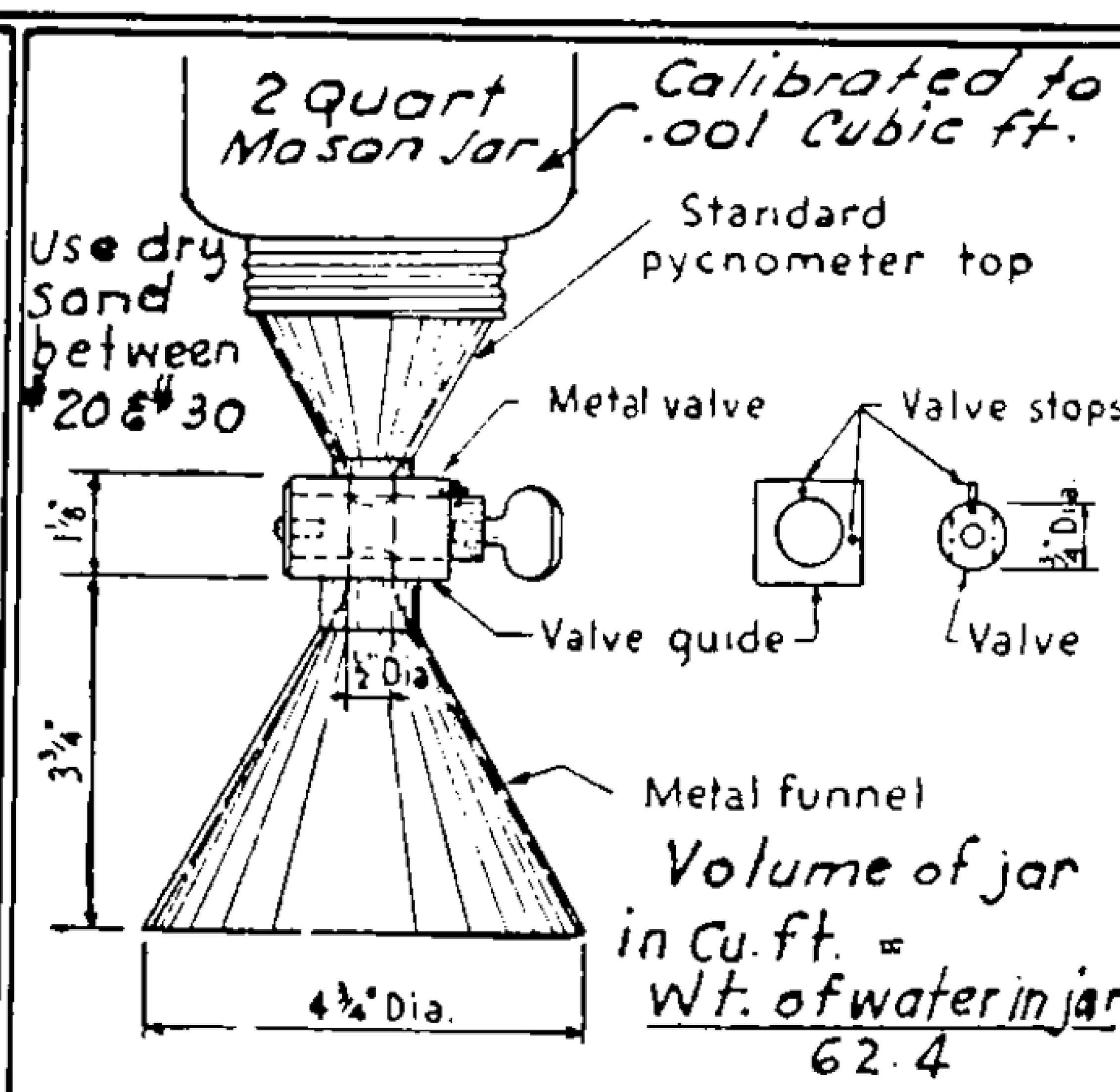


FIG. A - FIELD DENSITY DETERMINATION APPARATUS. DRY SAND METHOD.

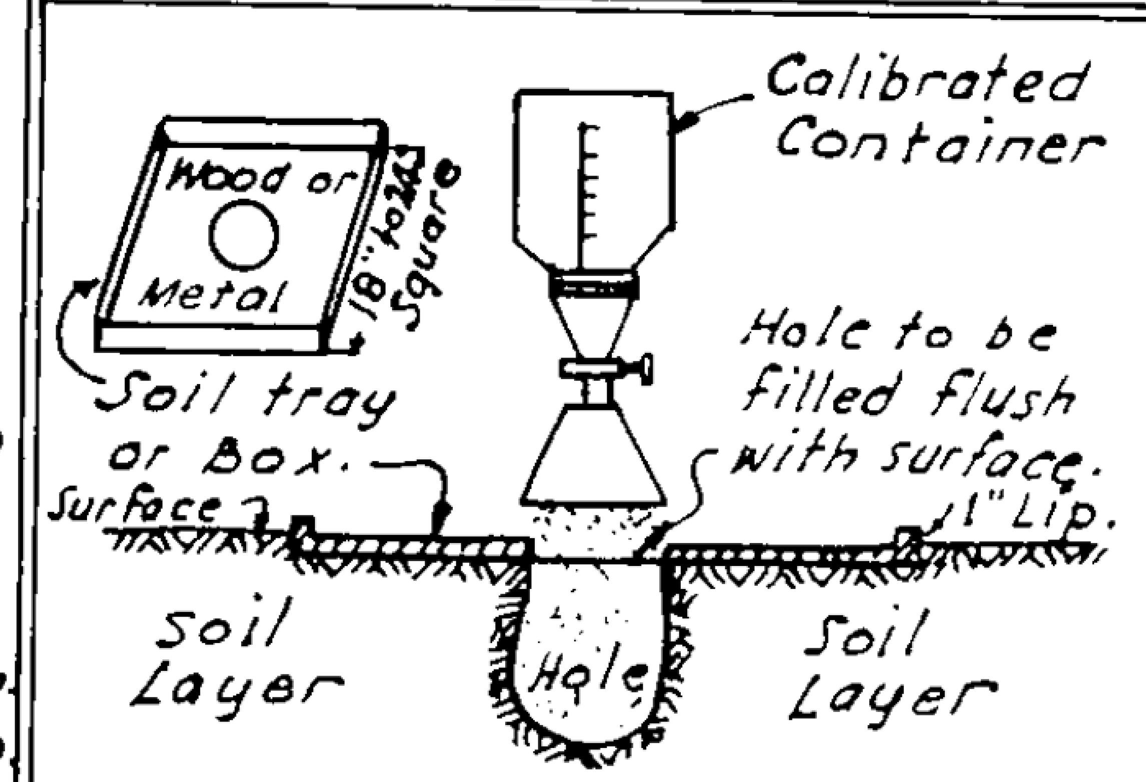


FIG. B - FIELD DENSITY TEST.

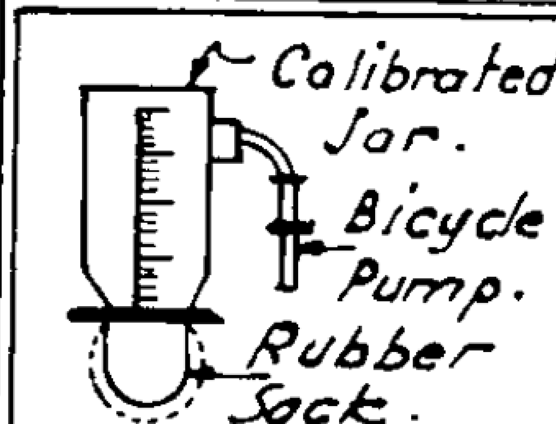


FIG. C - RUBBER SACK inflated to fill hole with known Volume of Water.

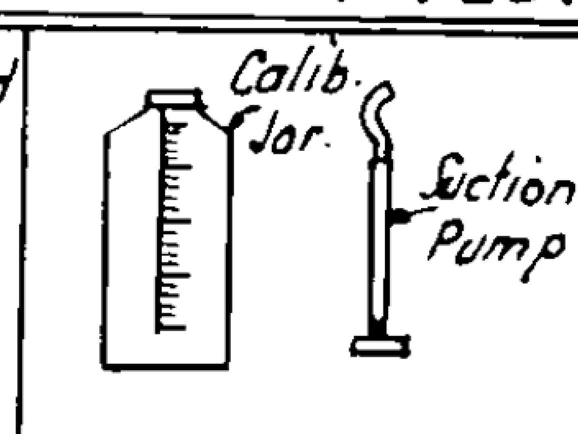


FIG. D - PUMP & JAR to fill hole with known Volume of oil. S.A.E. #40.

TABLE E - REL. BEARING VALUES & % COMPACTION REQUIRED.

MAX. DRY DENSITY	SOIL RATING	RECOMMEND. COMPACTION
90 lb. & less	N.G.	–
90 lb - 100 lb	Very Poor	95 - 100%
100 - 110 lb.	Poor to Very Poor	95 - 100%
110 - 120 lb.	Poor to Fair	90 - 95%
120 - 130 lb.	Good	90 - 95%
130 lb. & over	Excellent	90 - 95%

Note: Density or $\frac{\text{Wt.}}{\text{Vol.}}$ may be expressed as lb. per Cu. ft. or grams per Cu. Centimeter. Density in grams per C.C. = bulk specific gravity.

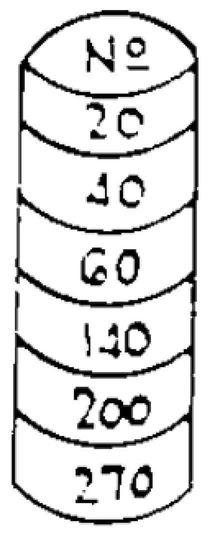
Chunk Sample Method: 1. Cut sample 4"-5" Dia. full depth of layer. 2. Determine % moisture. 3. Trim sample & weigh to 1/2 oz. 4. Immerse sample in hot paraffin, remove, cool & weigh again. 5. Compute vol. of paraffin using 55 lb. per Cu. ft. 6. Compute Vol. of sample by weighing in water (correcting for Vol. of paraffin). 7. Compute density data by formulas above.

Adapted from: Public Roads, Vol. 22, No. 12 by Harold Allen, Public Roads Administration.

SOILS – MECHANICAL ANALYSIS (GRAIN SIZE)

PURPOSE: 1. To identify homogeneous soils in the major divisions. See Pg. 3·01.
2. To classify soil mixtures occurring in a natural state, Table A & Fig. C, Pg. 3·02.
3. To classify soil into the P.R.A. or Casagrande groups. Pages 3·03, 3·04, 3·06, 3·07.
4. To design or control stabilized soil mixtures.
5. To determine frost heaving potentialities. See Pg. 3·17.
6. To determine Effective Size (D_{10}) & Uniformity Coefficient (C_u) for the design and control of filters and sub-drainage back fill.

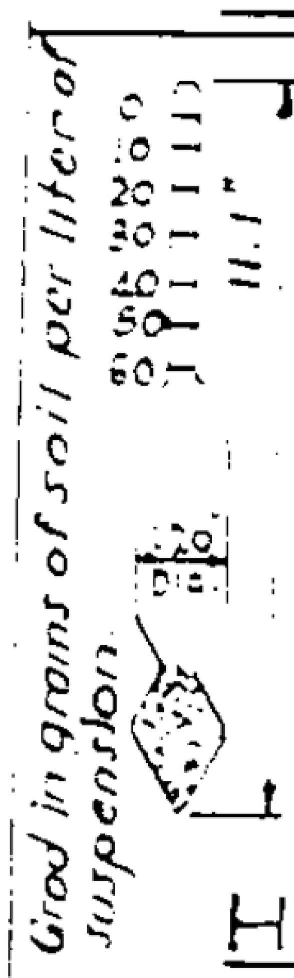
MM	Nº	INCHES
0.84	20	0.0331
0.42	40	0.0165
0.25	60	0.0098
0.105	140	0.0041
0.074	200	0.0029
0.053	270	0.0021



8" Frames brass

SIEVES

EQUIPMENT:
Balance sensitive to 0.1 gram
Mortar & rubber covered pestle.
Sieves: See left. In addition it is desirable to have #4, 10, 3/8, 3/4 & 1 1/2 for coarse grain soil.



Hydrometer analysis of grain size is based upon Stokes Law: "Particles of equal Specific Gravity settle in water at a rate which is in proportion to the size of the particle."
NOTE: This test requires Laboratory Technique.

HYDROMETER TEST.

SIEVE ANALYSIS.

Size of sample to be 400 to 750 grams – the coarser the material the larger the sample required.

Take sample by quartering or with sample splitter.

Dry surface moisture by heating the quartered sample at less than 212°F., or boiling point of water at high altitudes, in open pan until surface water disappears & sample is apparently dry and will not lose more weight with additional heating.

Break up cakes with mortar & pestle.

Record dry weight of sample.

Proceed to pass material through screens by placing sample in a stack of sieves, largest size on top, & shake vigorously with horizontal rotating motion balancing on bumper or pad until no more material will pass through each screen.

Weigh amount retained on each sieve, compute per cent of total weight of sample and plot curve.

Washing is recommended for Nº 200 sieves and smaller. Partly immerse the largest sieve in a pan of water and agitate. Take material and water from pan and repeat for next smaller size sieve. Agitate smallest size sieve in several water baths until water remains clear. Air-Dry portions retained in sieves, weigh & plot curve.

FIG. A – MECHANICAL ANALYSIS OF SOILS.

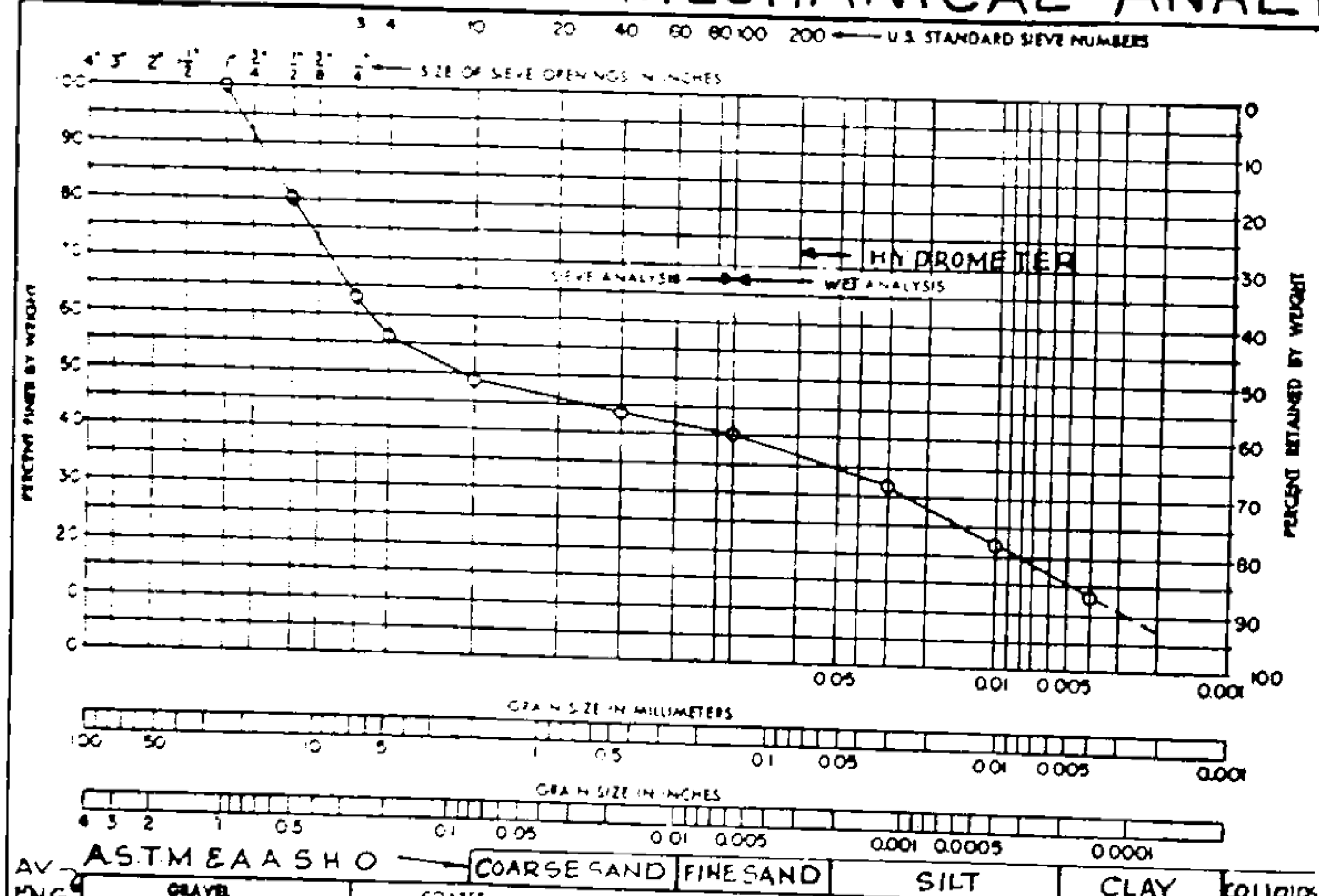
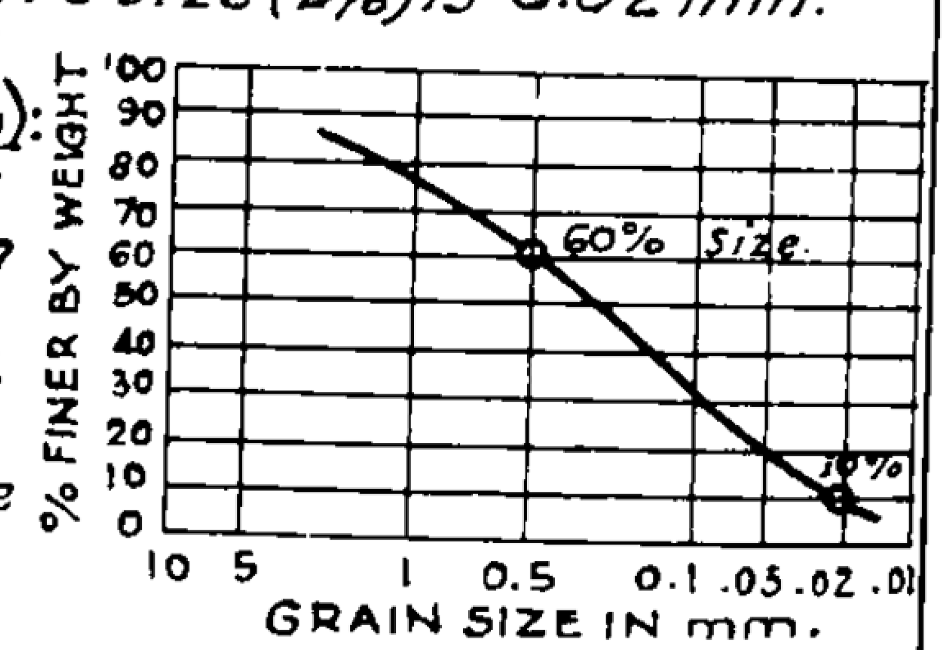


FIG. B – TYPICAL GRAIN SIZE CURVE.

EFFECTIVE SIZE (D_{10}): of a soil is the particle size that is coarser than 10% (by weight) of the soil, that is, 10% of the soil consists of particles smaller than the Effective Size (D_{10}) and 90% consists of larger particles. Example: in Fig. C Chart, Effective Size (D_{10}) is 0.02 mm.

UNIFORMITY COEFFICIENT (C_u): is computed by first determining the size that is coarser than 60% of the soil and dividing that size by the Effective Size (D_{10}), ie.,



$C_u = \frac{60\%\ Size}{10\%\ Size}$. Example: in chart, $C_u = \frac{0.5}{0.02} = 25$.

Note: The C_u of filter backfill should not be over 20. The D_{10} of non-frost heaving uniform soil is 0.02 mm. minimum.

FIG. C – EFFECTIVE SIZE (D_{10}) & UNIFORMITY COEFFICIENT (C_u).

SOILS — FROST

FROST ACTION SOILS: *Soils subject to frost action are well-graded soils containing more than 3 per cent by dry weight of particles less than 0.02 mm. (0.0008 inch) in size, and uniformly graded soils containing more than 10 per cent of particles less than 0.02 mm. in size. See Fig. B.

GENERAL: To prevent frost damage, the combined thickness of pavement and non-frost action base should be equal to the average depth of frost penetration as shown in Fig. A except as limited by Table C below.

Plasticity Index should be less than 6, preferably non-plastic and Liquid Limit less than 25 if soils are not subject to frost damage.

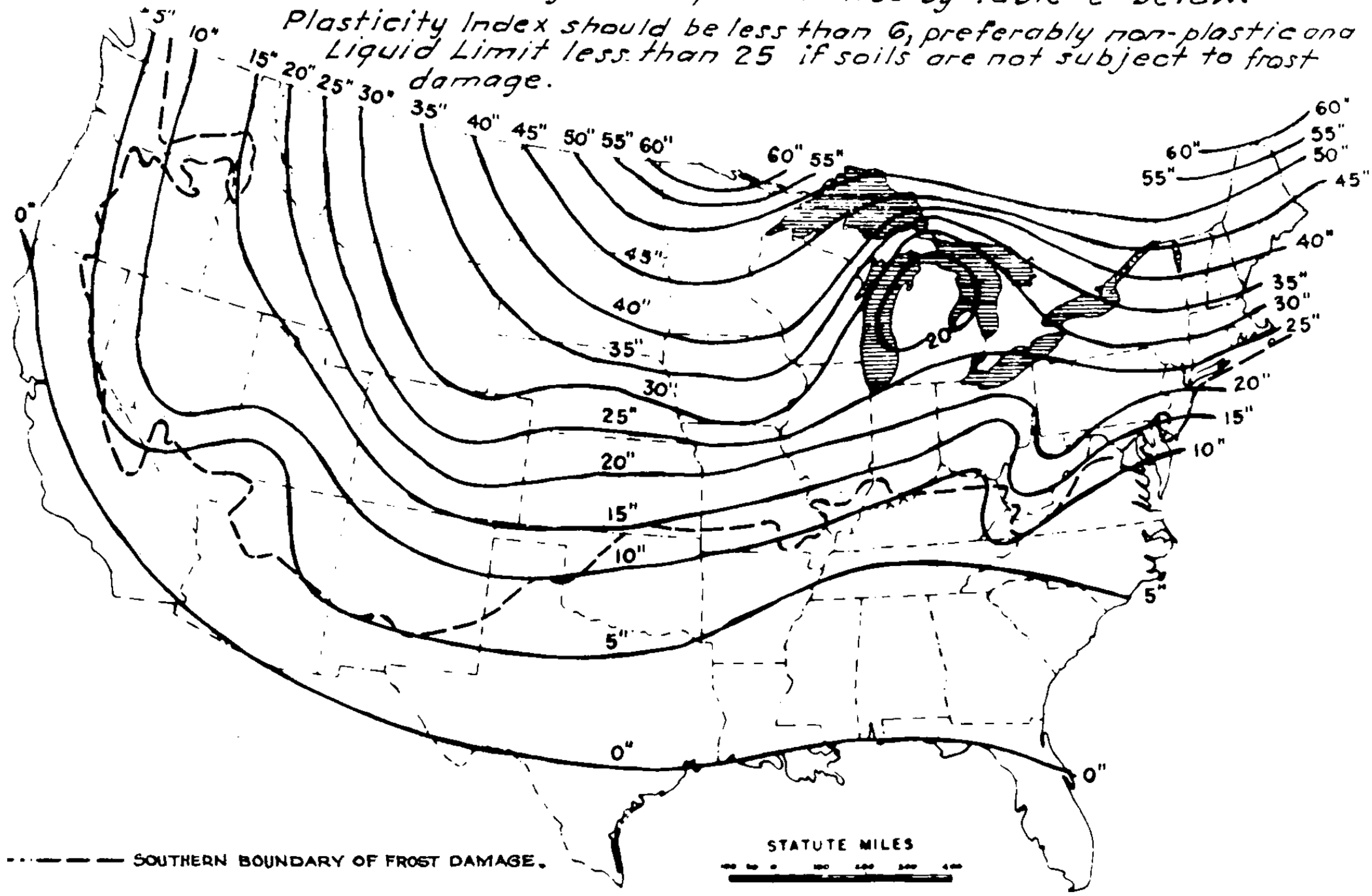


FIG. A - AVERAGE ANNUAL FROST PENETRATION** & SOUTHERN LIMIT OF FROST DAMAGE***

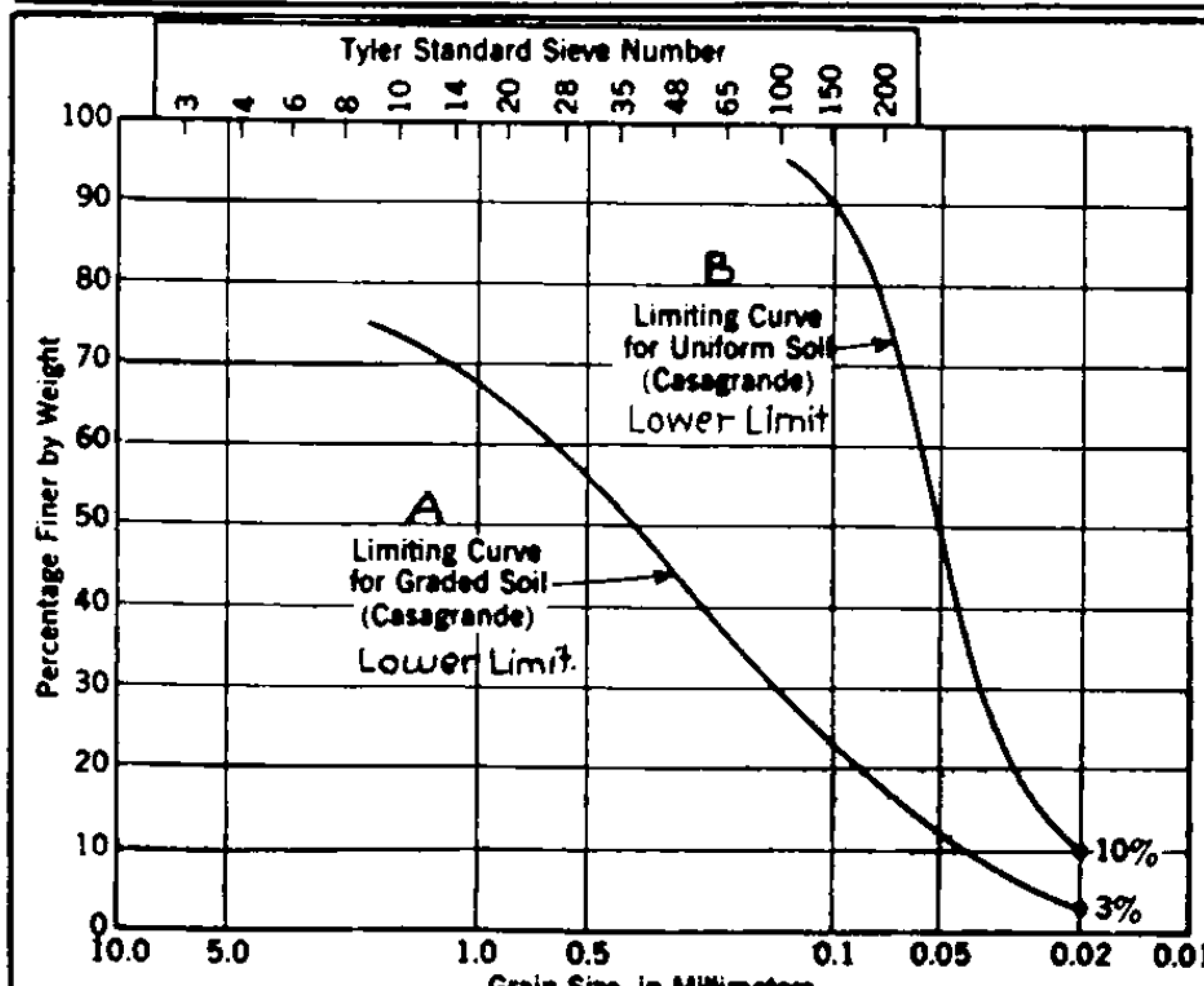


FIG. B - LIMITING CURVES FOR NON-FROST HEAVING SOILS (AFTER CASAGRANDE). ‡

See explanation for use of chart at right.

TABLE C - MAXIMUM REQUIRED THICKNESS IN INCHES OF PAVEMENT AND NON-FROST ACTION BASE.*

DESIGN WHEEL LOAD (POUNDS).	FINE GRAINED SUBGRADE.	COARSE GRAINED SUBGRADE.
15,000 and under	20 in.	15 in.
37,000	30 "	25 "
60,000	40 "	30 "

USE OF FIG. B.

Plot curve for soil in question on Fig. B. If the curve is close to curve A, the 3% limit for dry weight of particles less than .02 mm. is to be used. If the curve is close to curve B, the 10% limit shall be used. The Highway Research Board recommends all soils containing more than 8% by weight of particles, finer than 200 mesh be considered as soils subject to frost action.

*Adapted from: Aviation Engineers Manual, 1944, ** C.A.A. Design Manual, *** Highway Research Board 1943 Proceedings, D.J. Belcher and ‡ Civil Engineering, Vol. 12.

SOILS – SUBDRAIN FILTER

SEE SECTION ON DAMS FOR DESIGN OF DAM FILTERS.

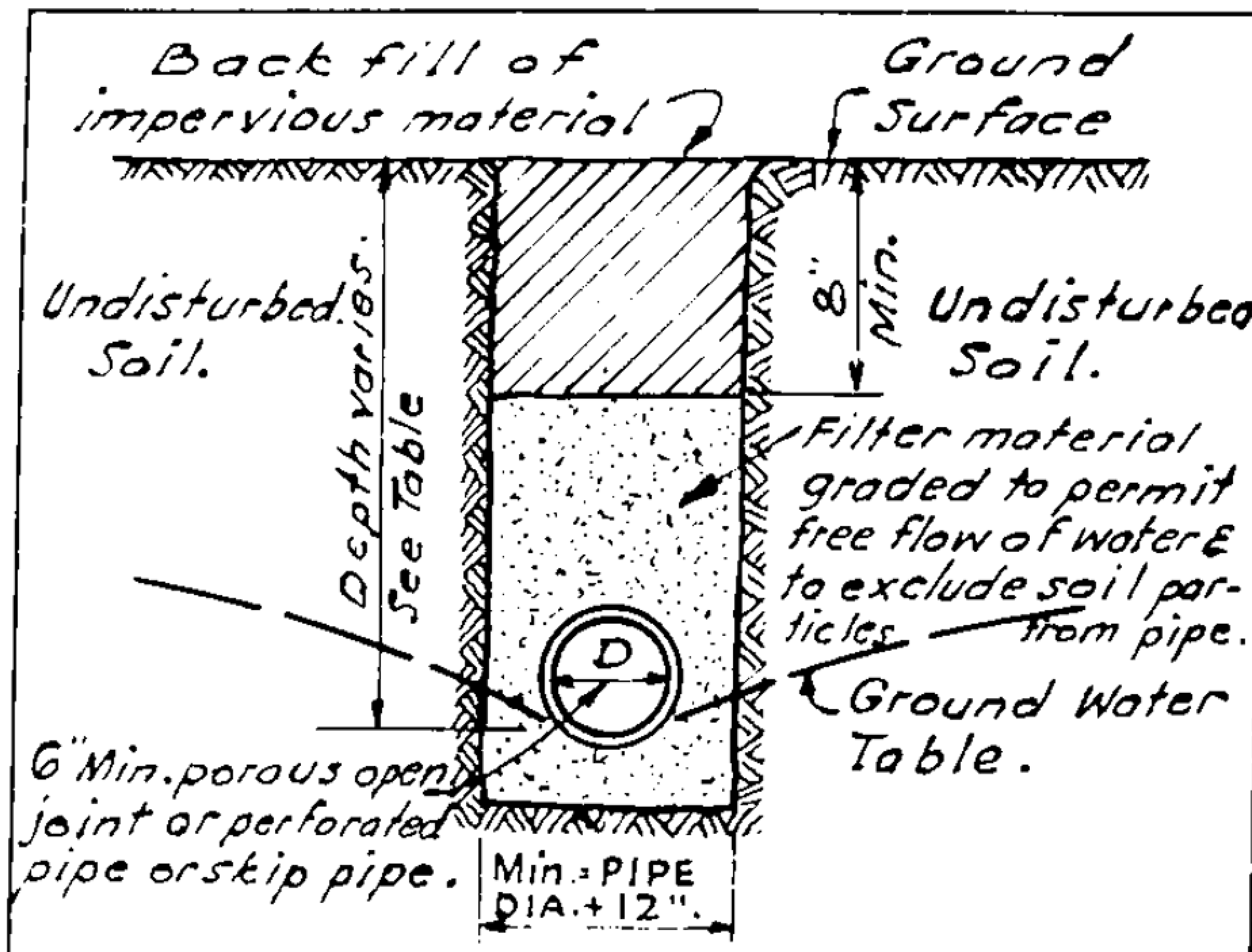


FIG. A - SUBDRAIN SECTION.

DESIGN CRITERIA FOR FILTER MATERIAL.

(1) $\dfrac{\text{15\% Size of filter material}}{\text{85\% size of subgrade material}}$ = less than 5

(2) $\dfrac{\text{15\% size of filter material}}{\text{15\% size of subgrade material}}$ = more than 5

(3) $\dfrac{\text{85\% size of filter material}}{\text{Size of pipe perforation or slot opening}}$ = more than 2

EXAMPLE FOR FIG. B

Given: Mechanical analysis of a subgrade, curve A; 3/8" holes in pipe drain.

Required: Gradation limits of filter material.

Solution:

Max. 15% Filter size - Criteria (1) = 5 x 0.25 = 1.25 (Pt. B).
Min. 15% " " " (2) = 5 x 0.018 = 0.09 (Pt. C).
Min. 85% " " " (3) = 2 x 3/8 = 3/4 (Pt. D).

Curve E, mechanical analysis of a proposed filter material satisfies criteria and should make satisfactory filter material for subgrade of this example.

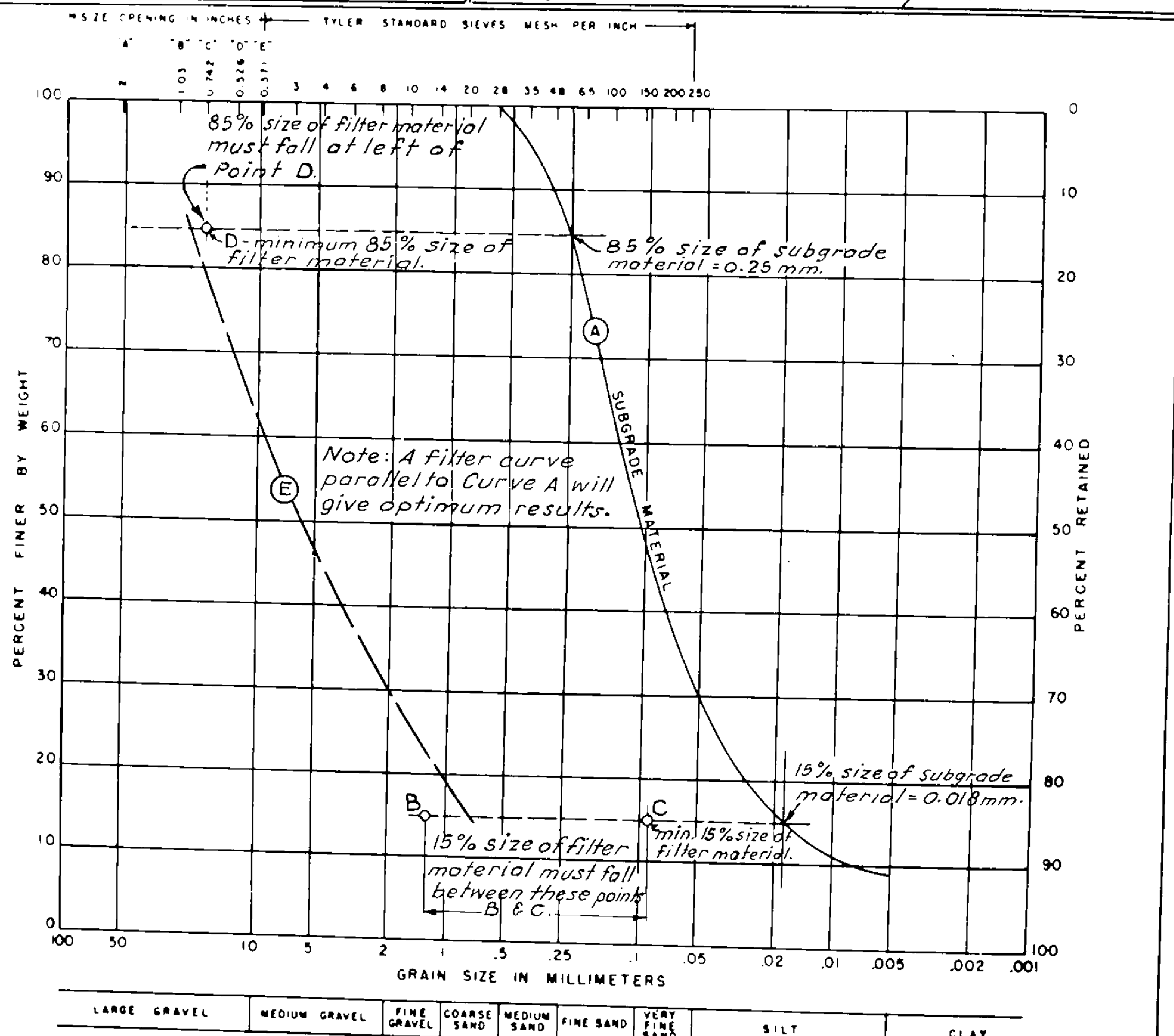


FIG. B - CURVES OF SUBGRADE & FILTER MATERIAL.
See Design Criteria and Example above.

After Dr. K. Terzaghi (1932) subsequently modified by U.S. Army Engineers (Manual - Chapt. XX), Feb. 1943

SOILS — STABILIZATION

STABILIZED SOILS: Should be sealed when used as a wearing course. Stabilization is mostly used to form base courses for thin bituminous or Portland cement concrete pavements.

MECHANICAL STABILIZATION: Plot curve of soil on chart in Fig. A. Curve should fall within shaded zone; otherwise coarse or fine material must be added to soil.

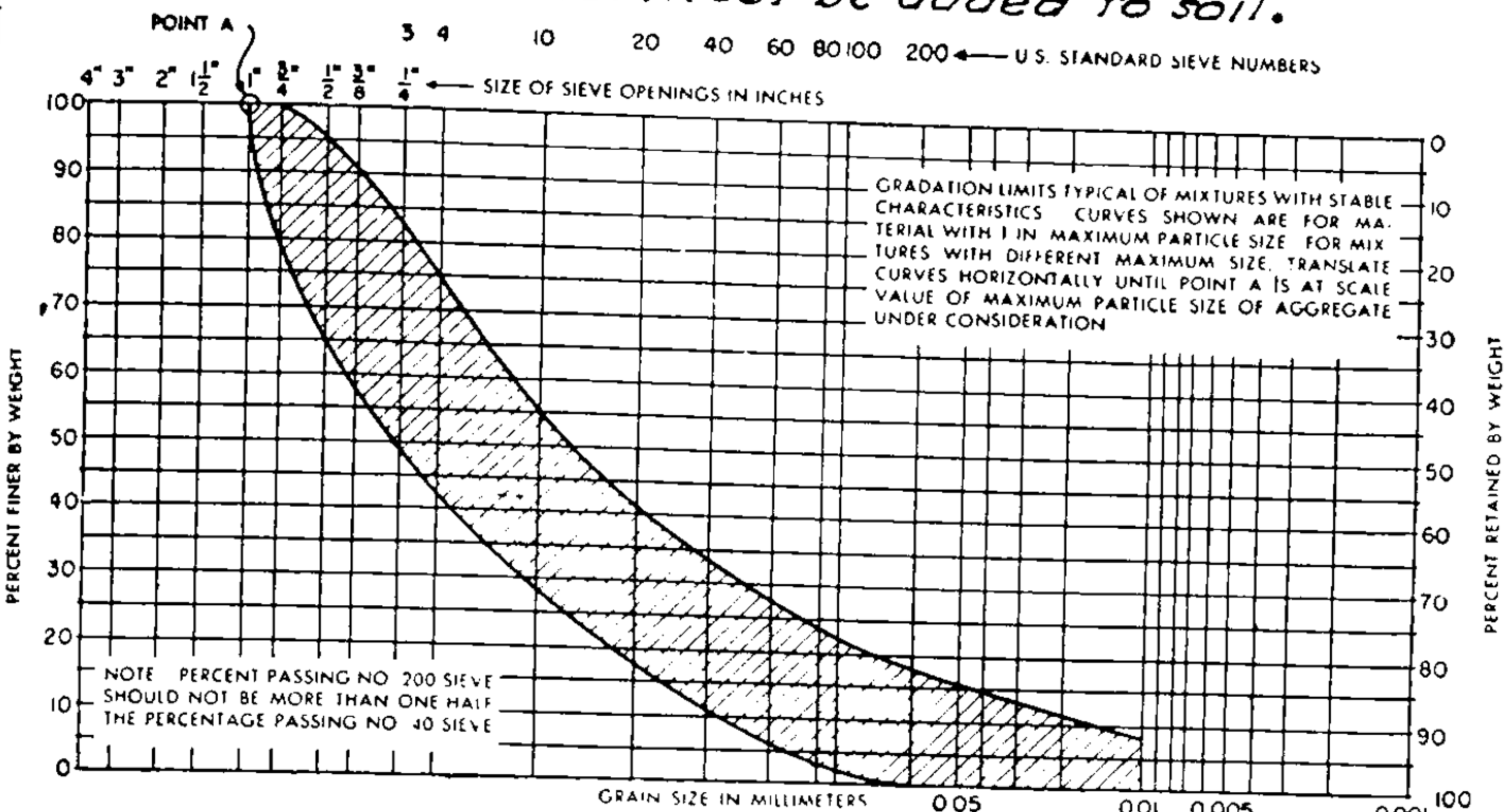


FIG. A - GRADATION LIMITS FOR STABLE MIXTURES.*

CRITERIA FOR MECH. STABILIZATION:

Plasticity Index (P.I.) of fraction of soil passing № 40 sieve should be from 3 to 9 but not over 6 if bituminous surface treatment is to be added.

The fraction passing № 10 sieve should show no appreciable shrinkage.

PORTLAND CEMENT STABILIZATION: The amount of cement to be added should be determined by laboratory analysis, Fig. B to be used as a guide only.

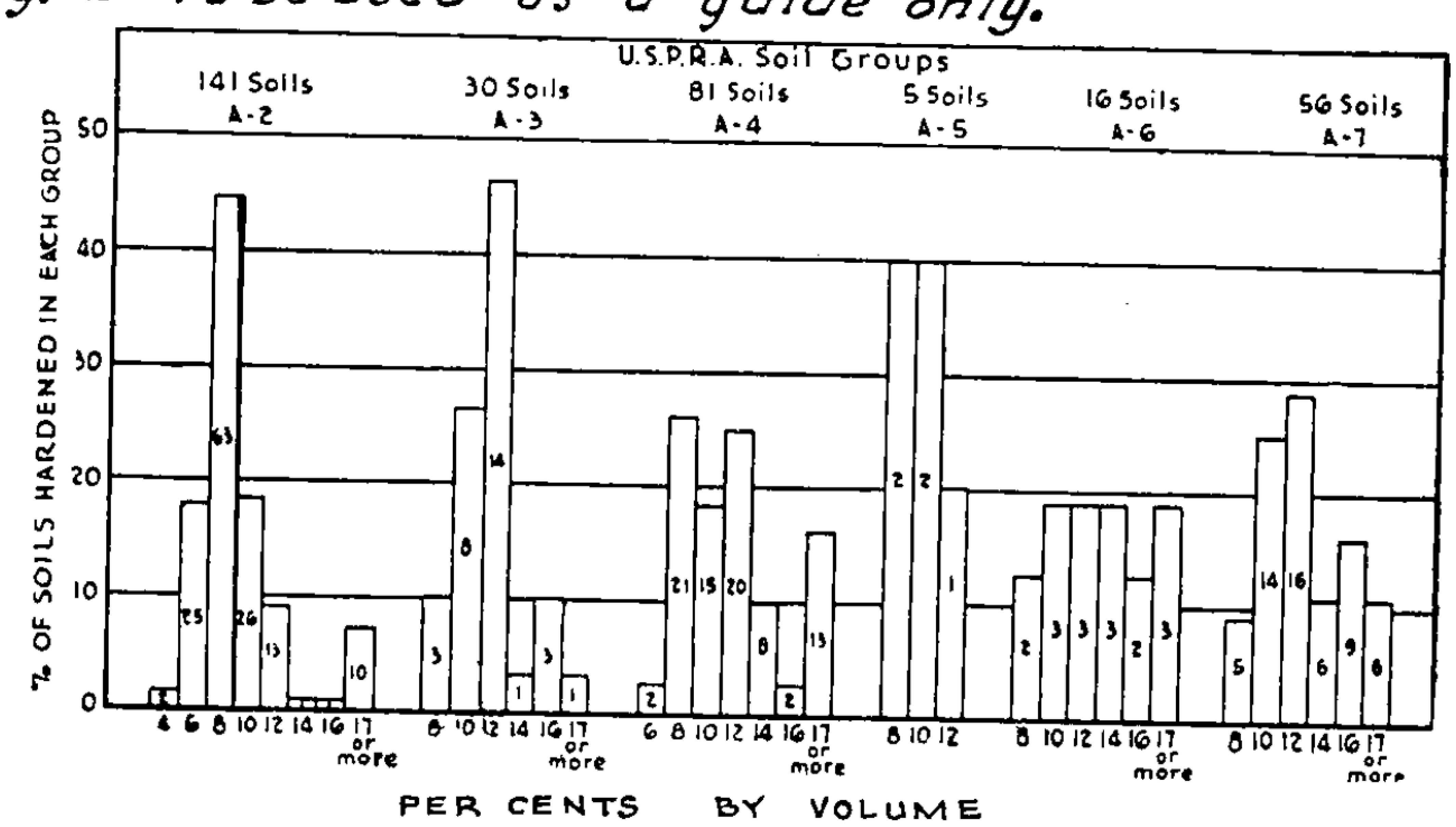


FIG. B - RESULTS OF TESTS OF SOILS TO DETERMINE CEMENT REQUIRED FOR ADDITIONAL BINDING.**

CRITERIA FOR CEMENT STABILIZATION.

Liquid Limit (L.L.) should not be more than 40.

Plasticity Index (P.I.) not more than 18.

Maximum depth of construction = 6".

Note: L.L. and P.I. values as recommended by the Portland Cement Assoc.

For cement treated base suggest A-3 type soil. See also Table A, Pg. 3-12.

BITUMINOUS STABILIZATION: Soil should be selected or native granular materials A1 to A3 types. The usual depth of construction is 2½" to 4". Amount of bituminous material would vary according to size with maximum requirement for fine soils. An average would be ½ gal. per sq. yd. for each inch of stabilized depth.

Bituminous materials usually used are cut-back asphalt MC2 or MC3, Road tars RT2 to RT5, Asphalt emulsion & slow curing liquid road oils. See Tables Pg. 3-78 & 3-79.

RESIN STABILIZATION: About ¼ of 1% by weight is required for normal application. The powdered resins (Vinsol, Stabinol, Pextite) are added to the soil in the same manner as cement. Up to the present, 1944, resins have been used successfully only with acid soils.

CALCIUM CHLORIDE STABILIZATION: Current practice is to use ½ lb. per sq. yd. per inch of compacted depth with a maximum of 3 lb. per sq. yd. Valuable in reaching desired densities and in preventing frost action.

LIST OF EQUIPMENT USED IN STABILIZATION: Chisel tooth, spike tooth and offset disc harrows; disc plows; motor patrol graders, dozers & other spreading equipment; rubber tired tractors; wobbly wheel, rubber tired, sheepsfoot, tandem & 3 wheel rollers, special mixing equipment as pre-mixing plants (Barber Greene type) & speed rotary tillers (Pulvi-mixers, Roto-Tillers).

*Adapted from Aviation Eng. Manual, Apr. 1944 **Highway Research Bd. Wartime Road Problems № 7.

SOILS - SHEARING STRENGTH & FOUNDATIONS

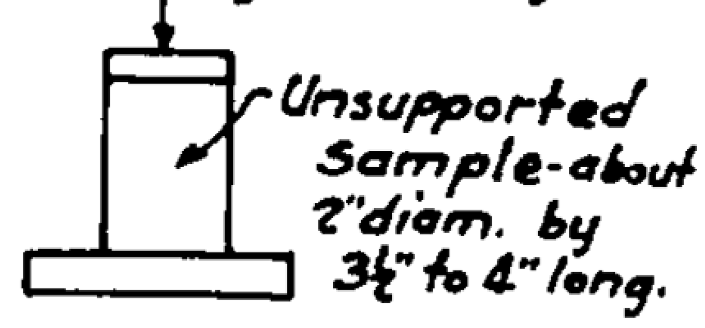
SHEARING STRENGTH OF SOILS:

Shearing Strength in lb. per sq. ft. $= W. \tan. \phi + C$ (Coulamb's Law). where W = Normal Load in lbs. per sq. ft.; ϕ = Angle of internal friction; C = Cohesive strength.

For very approximate values of ϕ and C see Table below and Table D, Page 4-74.

The determination of shearing strength and its application to foundations are matters requiring expert knowledge and at the best are in a controversial stage. Shearing strength of cohesive soils can be determined by quick shearing test below.

QUICK SHEARING TEST: (UNCONFINED COMPRESSION TEST APPLICABLE TO COHESIVE SOILS.)



Test sample without lateral support.

Max. Unit Shearing Strength = ½ Maximum Unit Load.

FOUNDATION DESIGN FOR BUILDINGS †

(GENERALIZATION AFTER DR. KARL TERZAGHI)

Compressibility of sands and silts varies with density. Compressibility of clay varies with water content which varies inversely with the cohesive strength.

Settlement of foundations on cohesive soils increases with the size of footing. Load tests are of little value except on cohesionless soils. In this case they should be performed in a standard fashion in a one sq. ft. area for purpose of comparison.

Investigation of all, even thin layers of material under a foundation should be made, as thin layers may be weak in shear and thus cause a settlement. Even at great depths weak layers can cause important settlement.

Silts are not necessarily a poor foundation if dense. They are however likely to be found in a loose state.

Settlements of groups of piles are always greater than those for single piles.

Resultant of a retaining wall should be at or near middle of base for cohesive soils because unequal settlement at toe may start a vicious cycle. Too much emphasis cannot be placed on drainage of rear of retaining walls.

Use of Elastic Theory to solve soil problems as given on Pg. 3-22 is condemned because the analogy is too far fetched. Best approach for check of soils particularly on soft foundations is the Most Dangerous Circle or Swedish Method.

CHECK OF BEARING VALUES FOR SOFT CLAY

Ultimate bearing capacity - square footings = 7.4 × Cohesion.

Ultimate bearing capacity - long rectangular footings = 5.7 × Cohesion.

For instance with a square footing if Cohesion = 1000#/sq. ft., ultimate bearing capacity = 7.4 × 1000 = 3.7 tons.

The safety factor recommended for Clays is 2 to 3.

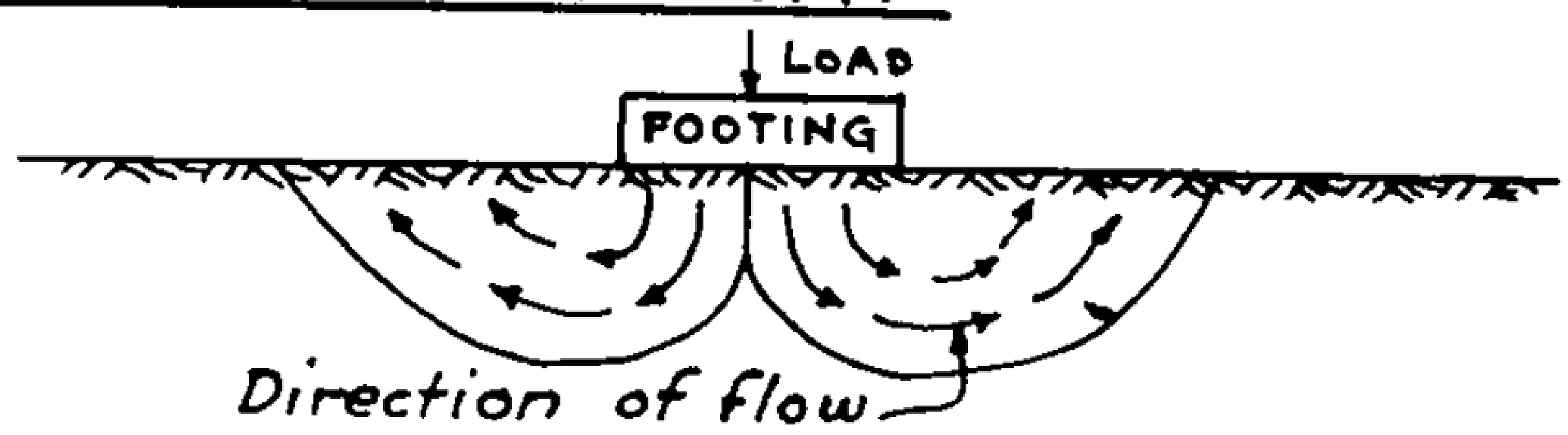


FIG. A · ACTION OF FOOTING ON SOFT CLAY

CHECK OF BEARING VALUES FOR SANDS

Check empirical soil values by following table.

DEPTH OF FOUNDATION	WATER TABLE	TYPE OF STRUCTURE	ALLOWABLE SOIL PRESSURE TONS PER SQ. FT.		
			DENSE	DOUBTFUL	FAIRLY LOOSE
5 ft. or more	At or below base	Ordinary	5	3	2
5 ft. or more	At or below base	Very Sensitive	3	2	1
2 ft. or less	Considerable depth	Ordinary	4	2.5	1.5
2 ft. or less	At base	Ordinary	2	1.2	0.8
2 ft. or less	Considerable depth	Very Sensitive	2.6	1.6	1
2 ft. or less	At base	Very Sensitive	1.3	0.8	0.5

NOTE- Importance of density and water level.

CHECK OF BEARING VALUES FOR STIFF CLAY

Same rules as for Soft Clay. Check empirical soil values also by following table.

CHARACTER OF SOIL	COHESION - C (TONS PER SQ. FT.)	TONS PER SQ. FT.	
		½ ULTIMATE	⅓ ULTIMATE
Stiff Clay	0.5 - 1	1.8 - 3.7	1.8 - 2.5
Very Stiff Clay	1 - 2	3.7 - 7.4	2.5 - 6.1
Hard Clay	over 2	over 7.4	over 6.1

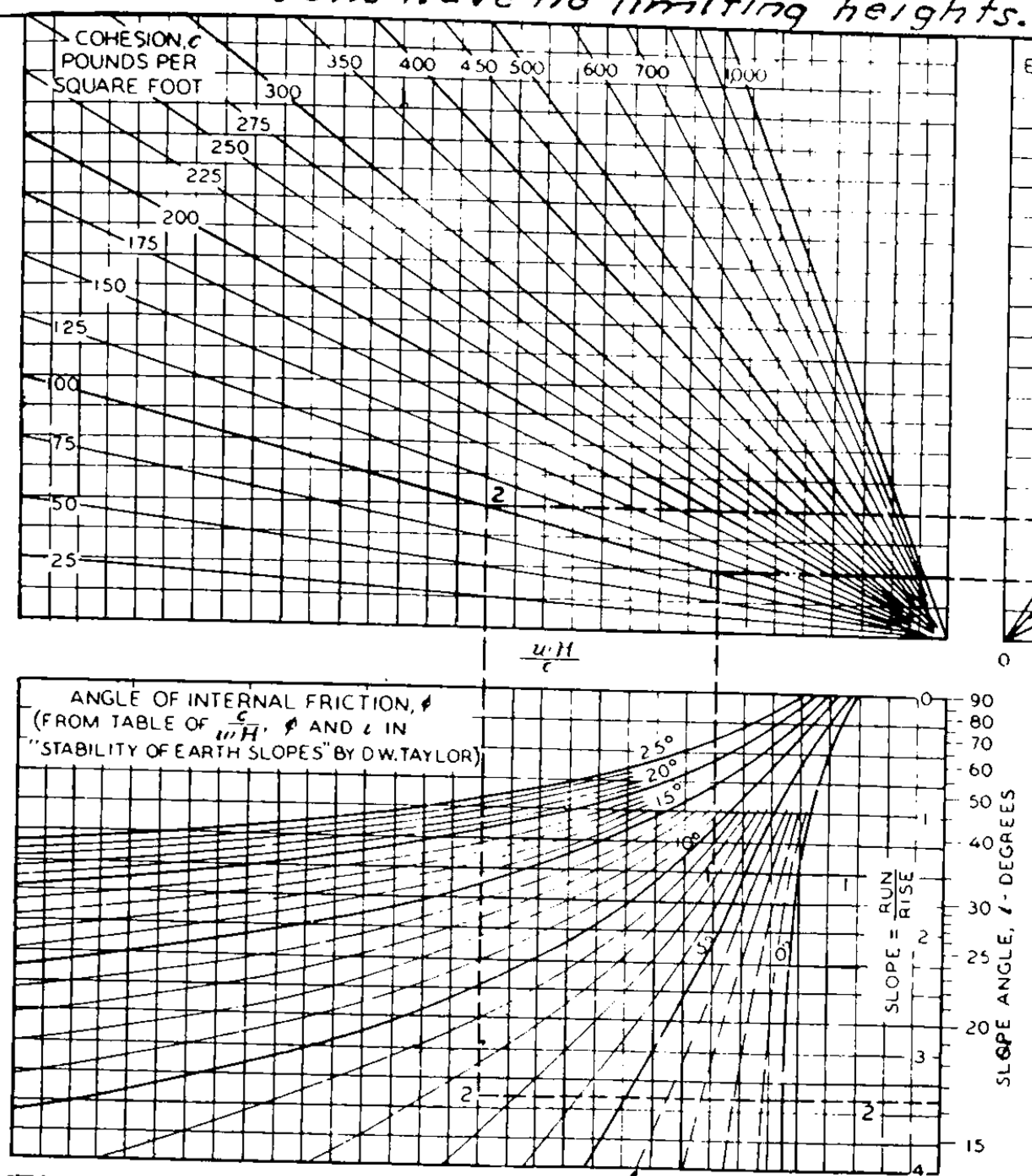
"Foundations of structures designed on the basis of empirical bearing values of soils should be considered adequate and safe only where such values have been thoroughly established by local practice and have proven sound by adequate experience in similar structures in the same localities. Otherwise, a complete analysis of the geology of the site should be determined, securing the necessary data by borings, test pits and other soil investigations. Complex geological formations or unusual foundation conditions may frequently require the advice and experience of specialists in foundation design and soil analysis." **

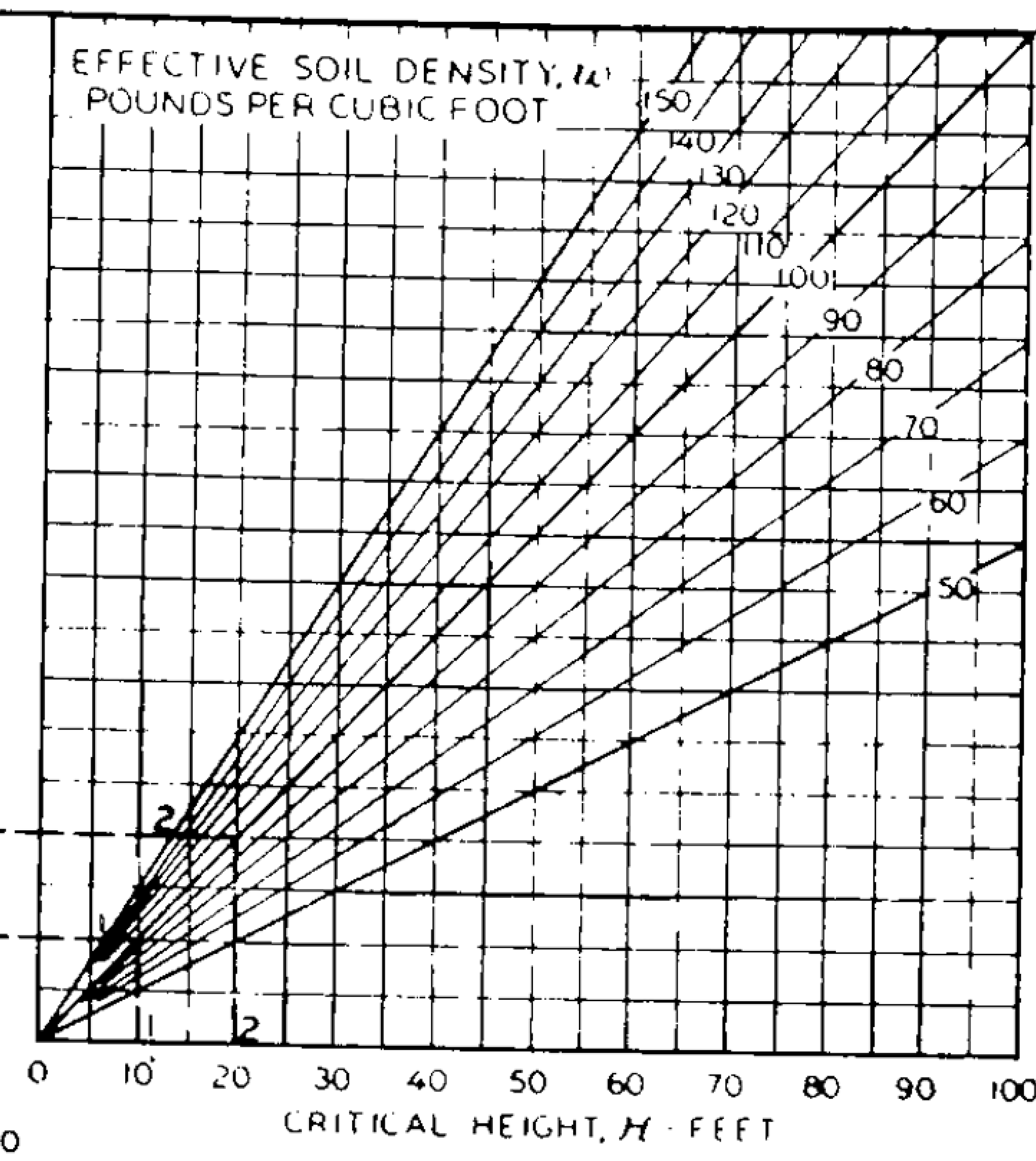
** Col. Carlton S. Proctor of Moran, Proctor, Freeman & Mueser.

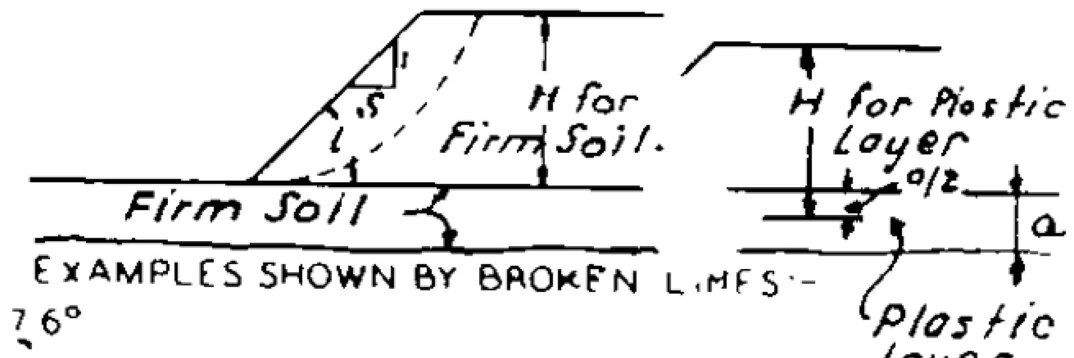
† See also Pages 2-50 to 2-69 for data on Foundations.

SOILS - EMBANKMENTS & RETAINING WALLS

LIMITATIONS: *All slopes of cohesive material require flatter angles as the height is increased. This limiting height will vary as to the degree of compaction, cohesive strength and angle of friction. It will also vary as to the strength of the foundation on which it rests.*
Granular soils have no limiting heights.







EXAMPLES SHOWN BY BROKEN LINES:-
IF φ = 7.6°
c = 100 POUNDS PER SQUARE FOOT AND
w = 100 POUNDS PER CUBIC FOOT
THEN FOR S = 1½, H = 10 FEET. (LINE 1-1-1-1-1)
OR FOR H = 20 FEET, S = 3.4, (LINE 2-2-2-2-2)

Note: This requires laboratory determination of cohesion and angle of internal friction, for approximate values: See p. 3-20 & Table D p. 4-74.

FIG. A - DETERMINATION OF EMBANKMENT SLOPES & HEIGHTS*

RETAINING WALLS† *(After Dr. Karl Terzaghi).*

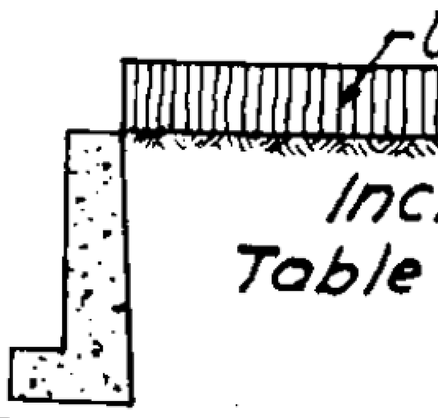
TABLE B.- DATA FOR ESTIMATING EARTH PRESSURE ON THE BASIS OF EQUIVALENT FLUID EARTH.

Description of Backfill.	w lb/cu.ft.	w' lb/cu.ft.	Cohesion lb/sq.ft.	H_o ft.
1. Coarse grained backfill without admixture of fine soil particles, very permeable.	110	27	–	0
2. Coarse grained backfill with low permeability due to admixture of soil particles with silt size.	115	35	–	0
3. Residual soil with stones, loamy sand and other backfill materials with conspicuous clay content.	115	45	–	0
4. Plastic clay.	120	120	200	4.3
5. Soft clay or mud.	100	100	0	0

w = Weight of material lb./cu.ft.
c = Cohesion lb./sq.ft.
For clay: $w = w'$; $H_o = \frac{2.5c}{w}$.
For soils #1 to #3 in Table B, on compressible footing, increase w' by 50%.

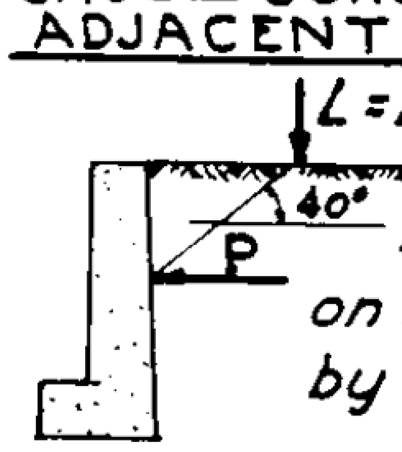
RETAINING WALLS WITH SURCHARGE LOADS.

CASE I - UNIFORM SURCHARGE.



Increase w' given in Table B by: $q\frac{w'}{w}$.

CASE II - SURCHARGE DUE TO AN ADJACENT VERTICAL LOAD.



Horizontal load per l.f. on back of wall caused by $L = P = L\frac{w'}{w}$.

CASE III - SLOPING SURCHARGE.

Top of equivalent fluid.
$w'' = w'[2 - (\frac{H - H_1}{H})^2]$
w'' = Equivalent fluid pressure behind wall.
if $H_1 > H$, $w'' = 2w'$.

Check for Sliding on Clays: *Shear must be less than ½ bearing capacity of soil.*

* Adapted from Eng. News Record. Vol. 128 - No. 7. dated Feb. 12, 1942 article by P.R.A.
† See also Pg. 2-68, 2-69 for data on retaining walls.

SOILS - EMBANKMENT FOUNDATIONS

ELASTIC THEORY:- *Based on Boussinesq equation.*
CAUTION:- *In applying this to soils, it is to be remembered that it is based on a foundation of homogeneous, isotropic material of infinite depth, modulus of elasticity independent of depth, which are not the usual properties of soils.*

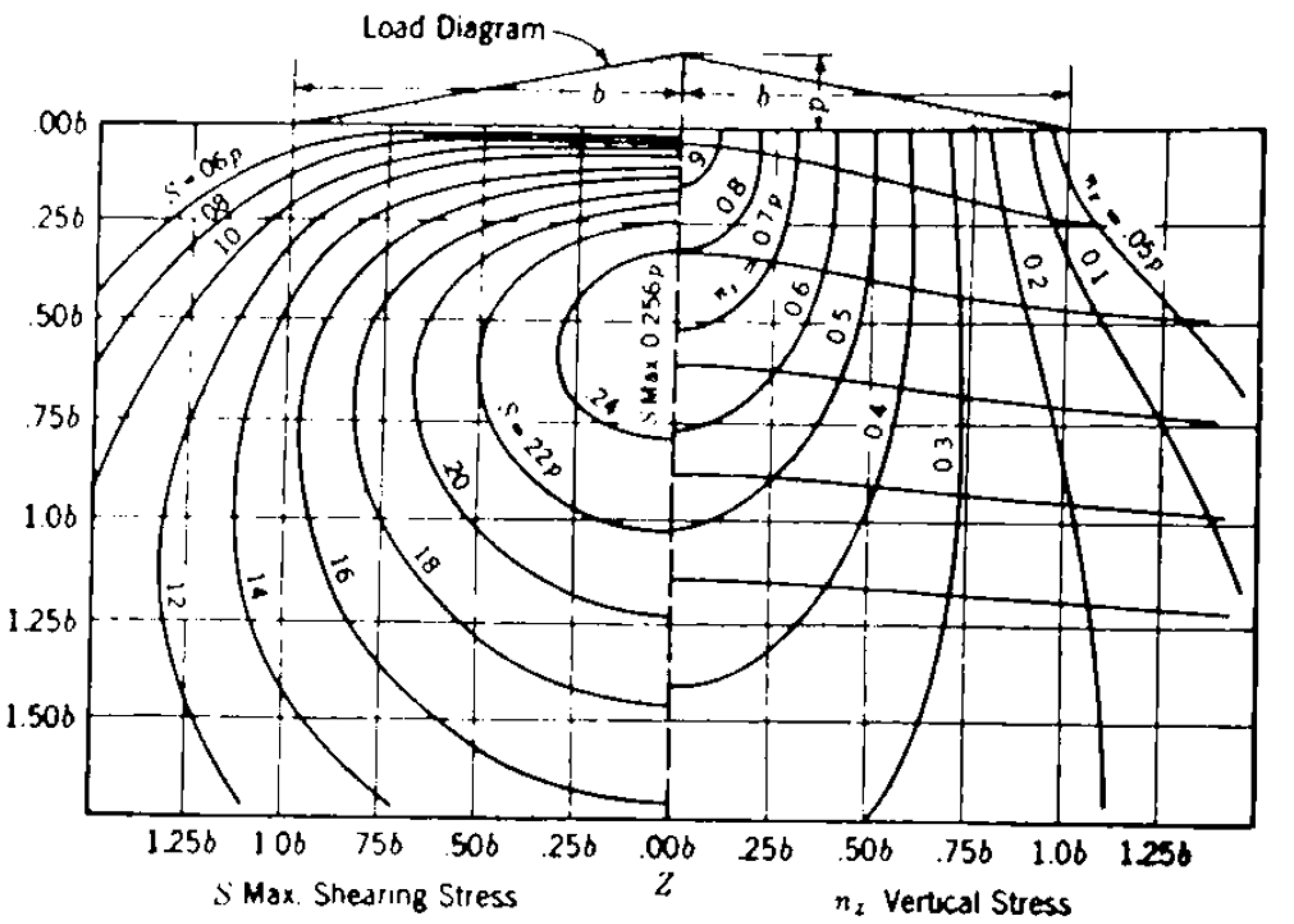


FIG. A - TRIANGULAR LOADING.

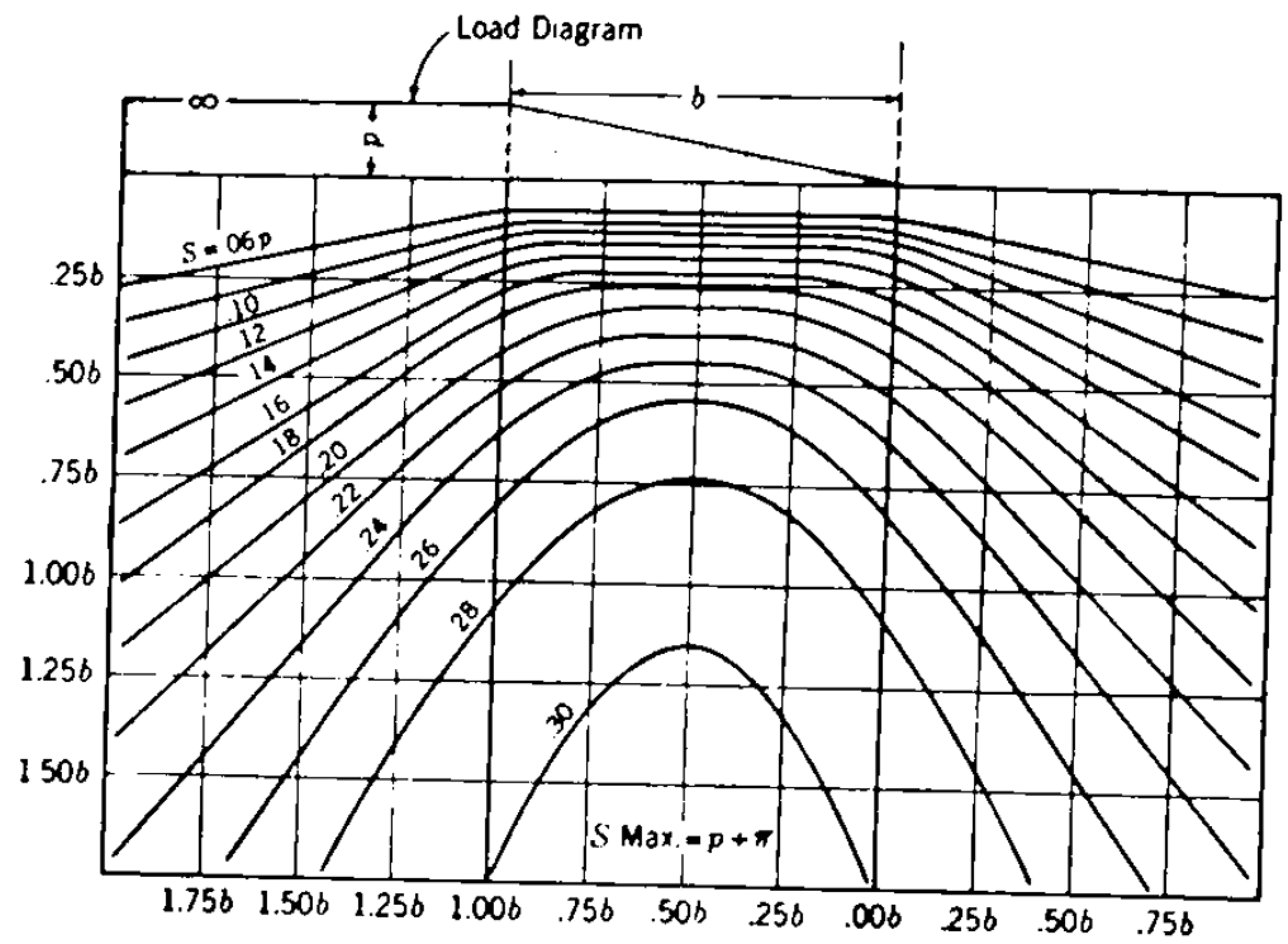


FIG. B - TERRACE LOADING.

DISTRIBUTION OF SHEARING STRESSES UNDER EMBANKMENTS.*

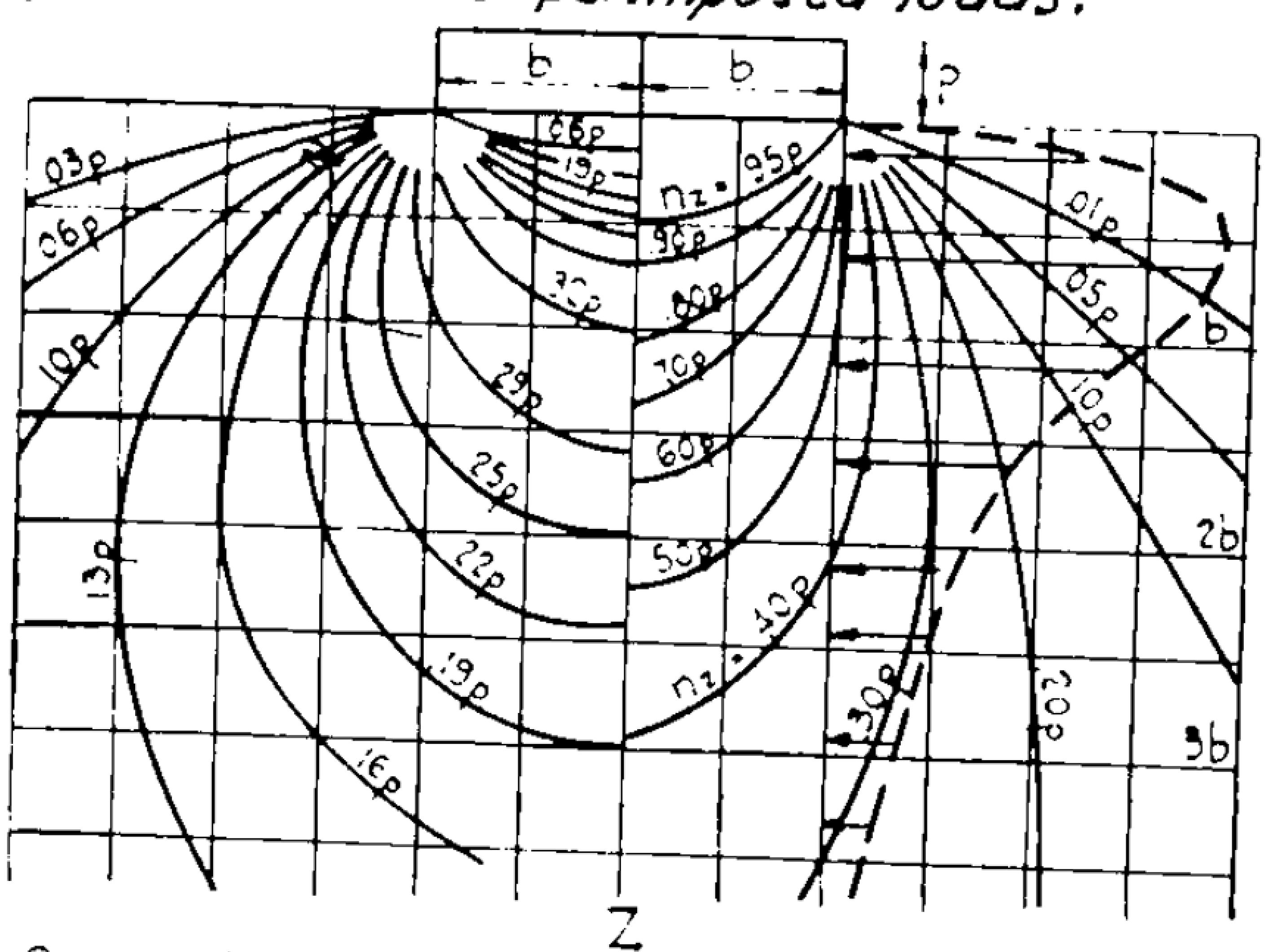
S= Shear per sq. ft.; p= Load per sq. ft. on foundation at ℄ of dam. Foundation of homogeneous isotropic material, infinite depth.

USE OF DIAGRAMS:* Given:- *Embankment 100 ft. high; foundation material = fine silt with tan. ϕ =0.4 and C=0, weight = 120#/cu. ft., b = 200 ft.*
Required:- *Factor of Safety at depth 0.5 b.* Solution:- *In Terrace loading Fig. B diagram at 0.5b, max. unit shear = 0.25 p =* $\frac{0.25 \times 100 \times 120}{2000}$ *= 1.5 tons/sq. ft. Unit Shearing strength = W. tan. ϕ + C. W = unit weight x total depth at point of max. unit shear (midpoint of slope = 100+50) ∴ Unit shearing strength =* $\frac{150 \times 120}{2000} \times 0.4 + 0 = 3.6$ *tons/sq. ft. factor of safety =* $\frac{3.6}{1.5} = 2.4$

MIN. FACTOR OF SAFETY:- *Try solution at other depths, 0.25 b, 0.375 b, 0.75 b, etc.*

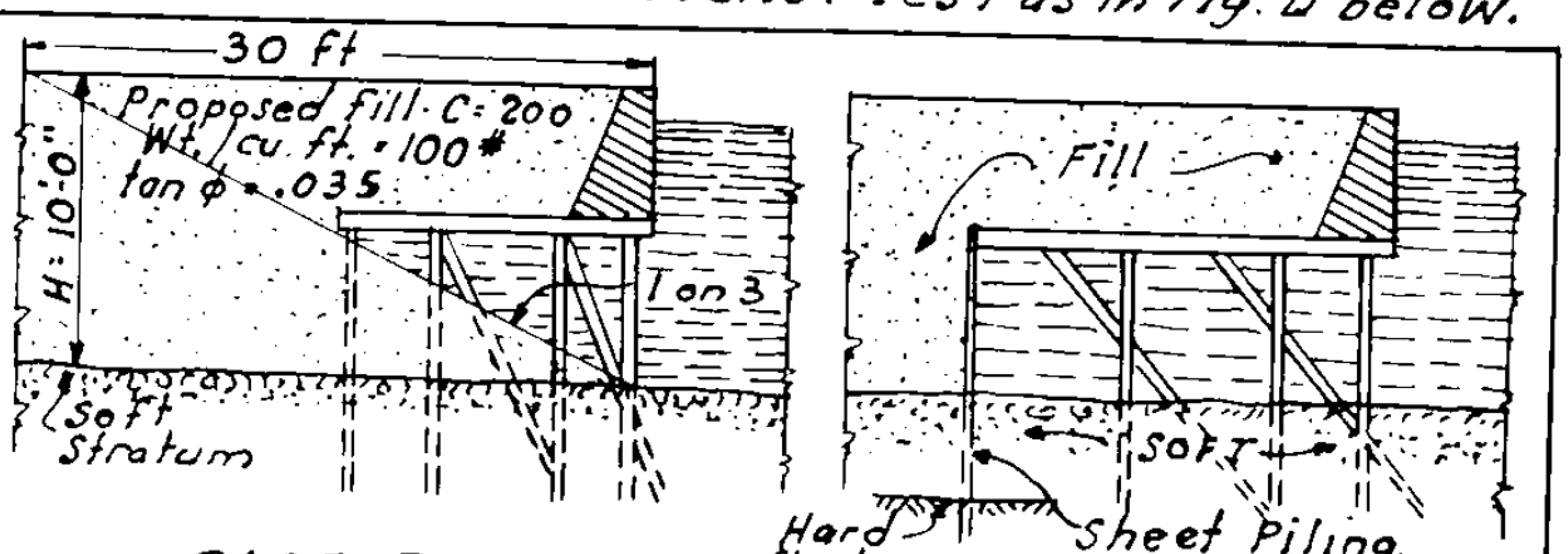
Notes: 1.- *Justin, Hinds & Creager prefer using Terrace Loading rather than Triangular loading for dam embankments.*
2.- *Applicable only to homogeneous isotropic foundations of infinite depth.*
3.- *Applicable to fill such as on soft harbor foundations. Test as in Fig. D below.*

Note: Dotted line indicates possible distribution, according to Elastic Theory of horizontal pressure from superimposed loads.



P-Lbs. per sq. ft. distributed Load.

FIG. C - DISTRIBUTION OF SHEARING STRESSES UNDER LONG FOOTING.**



CASE I

Check for shearing strength of soft foundation stratum as follows:

EXAMPLE: *Test soft stratum for support of Embankment.*
By Fig. B - Max. Unit Shear = 0.25p = 0.25 x 10 x 100 = 250.
Unit Shearing Strength at 0.5 b = W. tan.φ + C = 25 x 100 x .035 + 200 = 287.5
[Where depth at 0.5 b = (10 + $\frac{30}{3}$) = 25]
Safety factor = $\frac{287.5}{250}$ *= 1.1 inadequate.*

CASE II

If sheet pile and platform is strong enough to resist horizontal thrust of soft foundation and fill and adequately tied into hard stratum no further check of shearing stress is necessary.

FIG. D - CHECK FOUNDATION OF FILL BEHIND RELIEVING PLATFORM.

* *From The Application of Theories of Elasticity and Plasticity to Foundation Problems by Leo Jürgenson, J. Boston Soc. Civil Engrs., July 1934, adapted by Justin, Hinds & Creager.* ** *Adapted from Plummer & Dore, Soil Mechanics & Foundations, Pitman Pub. Corp.*

SOILS – SLOPES & EMBANKMENTS

SLOPE OF REPOSE*

(Not to be used for Safe Slopes - pg. 3-21)

Kind of Earth	Slope of Repose ⊗
Sand, clean	1 on 1.5
Sand and clay	1 on 1.33
Clay, dry	1 on 1.75
Clay, damp, plastic	1 on 3
Gravel, clean	1 on 1.33
Gravel and clay	1 on 1.33
Gravel, sand and clay	1 on 1.5
Soil	1 on 1.33
Soft rotten rock	1 on 1
Hard rotten rock	1 on 1
Bituminous cinders	1 on 1
Anthracite ashes	

For cohesive soils - see limitations, pg. 3-20 & 3-21 (safe slope varies with height).
For granular soils - a slope flatter than the slope of repose may be assumed as a safe slope without regard to height.
Safe slope commonly assumed in practice - 1 on 1½ to 2.

SUBMERGED SLOPES

(Determination of safe slopes by investigation is indicated)

Safe slopes for granular material - may be taken as same as for slopes not submerged.
Cohesive material safe slope - may vary from 0 to vertical.
Material on which fill rests an important factor in determining safe slopes.

ANGLE OF REPOSE* OF SUBMERGED SLOPES MATERIAL EXCAVATED BY WET OR DRY PROCESS AND DUMPED INTO WATER

Material	Slope of Repose ⊗
Sand, clean	1 on 2
Sand and clay	1 on 3
Clay	1 on 3½
Gravel, clean	1 on 2
Gravel and clay	1 on 3
Gravel, sand and clay	1 on 3
Soil	1 on 3½
Soft rotten rock	1 on 1
Hard rock, riprap	1 on 1
River mud	1 on 3 to 1 on 20

SUBMERGED EXCAVATED SLOPES (Rule of thumb)

Sand	1 on 2
Clay	1 on 1½ to vertical
Stiff mud	1 on 1 to vertical
Sluiced mud	1 on 10 to 1 on 20

* *Adapted from American Civil Engineers Handbook by Merriman & Wiggin.*
⊗ *"For cohesive soils these slopes apply only to heights of less than 20'; for non-cohesive soils no limit as to height."*

SOILS - EMBANKMENT SHRINKAGE & PERMEABILITY

EMBANKMENT SHRINKAGE

CASE I - Yield of borrow in finished embankment.

$$\text{Volume} = \frac{\text{Weight}}{\text{Density}}$$: Volume varies inversely as density.

Assume $\begin{cases} \text{borrow pit dry density} = 110 \text{ lbs. per cu. ft.} \\ \text{embankment dry density} = 125 \text{ lbs. per cu. ft.} \end{cases}$

Then 1 cu. yd. of borrow will yield 110/125 cu. yd. embankment.

CASE II - Shrinkage after embankment compaction.
This will be zero if embankment is compacted to maximum density. In ordinary practice, i.e. power equipment wheel compaction - no rollers, no moisture control - it may be taken as:
Sand and gravel - 1 to 2%* — Clay or loam - 2 to 3%*
Certain deposits such as expansive clays swell in embankments.

CASE III - Loss by waste, of improper material such as top soil or muck, should be allowed for.

TABLE A - VOLUME OF BORROW REQUIRED FOR 1 CU. YD. OF EMBANKMENT.

(Empirical rules for use where densities are not obtainable. Power equipment wheel compaction, not rolled.)

Gravel	1.09*	1.12**	Light sandy earth	1.14*	1.20**
Gravel and sand	1.10*	1.13**	Vegetable surface soil	1.18*	1.24**
Clay and clayey earth	1.11*	1.15**	Ledge rock		0.70**

PERMEABILITY See also Pg. 3-25.

TABLE B - PERMEABILITY DATA. †

COEFFICIENT OF PERMEABILITY (k) in cm. per sec. (Log scale)

Turbulent flow (k above 1.0) — Perfect validity of Darcy's law (k below 10^{-7})

k = 10^{2}, 10^{1}, 1.0, 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}, 10^{-7}, 10^{-8}, 10^{-9}

DRAINAGE PROPERTY	Good drainage		Poor drainage	Practically impervious
APPLICATION IN EARTH DAMS AND DIKES	Pervious sections of dams and dikes		Impervious sections of dams and dikes	
TYPES OF SOIL	Clean Gravel	Clean sands; Clean sand & gravel Mixtures	Very fine sands; Organic & Inorganic silts; mixtures of sand, silt & clay; glacial till; stratified clay deposits; etc.	"Impervious" soils e.g. homogeneous clays below zone of weathering
		"Impervious soils" which are modified by the effects of vegetation and weathering		
DIRECT DETERMINATION of coefficient of permeability	Direct testing of soil in its original position (e.g. well points) if properly conducted - reliable - considerable experience required			
	CONSTANT HEAD PERMEAMETER Little experience required			
	FALLING HEAD PERMEAMETER: Reliable little experience required	Unreliable Much experience necessary for correct interpretation	Fairly reliable Considerable experience necessary	
INDIRECT DETERMINATION of coefficient of permeability	COMPUTATION from the grain size distribution (e.g. Hazen's formula) only applicable to clean cohesionless sands & gravels			
	HORIZONTAL CAPILLARITY TEST Very little experience necessary. Especially useful for rapid testing of a large number of samples in the field without Lab. facilities			COMPUTATIONS from consolidation tests; expensive Lab. equip. & considerable experience required

* From Am. C. E. Handbook by Merriman & Wiggin. ** In accordance with modern highway practice.
† Adapted from Publication No. 268, Harvard Grad. School of Eng.

SOILS - VOIDS RATIO & PERMEABILITY

DETERMINATION OF VOIDS RATIO = e

EXAMPLE: Weight of Soil = 120 pounds per cubic foot.
Specific Gravity of grains = 2.70
2.70 x 62.4 = 169 lb./cu.ft. - Theoretical weight of solid material.
120/169 = 0.71 cu.ft. - Volume of Solid material.
1.00 - 0.71 = 0.29 cu.ft. - Volume of voids.

$\frac{0.29}{0.71} = 0.41$: VOIDS RATIO.

PERMEABILITY

Darcy's Law : $Q = kA\frac{H}{L}$ for flow of water through soil.

WHERE:

Q = Volume of Flow in cu.ft. per min.
k : Coefficient of permeability - for values see Table A.
A = Area in sq. ft. of cross-section under consideration.
$\frac{H}{L}$ = Hydraulic Gradient.

TABLE A - COEFFICIENTS OF PERMEABILITY (k) in ft./min. for 60°F.

EFFECTIVE SIZE	Porosity $= \frac{e}{1+e}$										
	30 percent	32 percent	34 percent	36 percent	38 percent	40 percent	42 percent	44 percent	46 percent	48 percent	50 percent
0.01	0.00003	0.00004	0.00005	0.000060	0.000072	0.000085	0.000101	0.000123	0.000149	0.000181	0.000215
0.02	.00013	.00016	.00020	.000239	.000286	.000339	.000405	.000492	.000597	.000724	.000861
0.03	.00030	.00036	.00045	.000538	.000645	.000763	.000911	.00111	.00134	.00163	.00194
0.04	.00053	.00065	.00079	.000958	.001145	.001355	.00162	.00197	.00239	.00290	.00344
0.05	.00082	.00101	00124	.001495	.001790	.002120	.00253	.00307	.00373	.00452	.00538
0.06	.00118	.00146	.00178	.002150	.002580	.003050	.00364	.00442	.00537	.00652	.00775
0.07	.00161	.00198	.00243	.002930	.003510	.004155	.00496	.00602	.00732	.00887	.0105
0.08	.00211	.00259	.00218	.003825	.004585	.005425	.00647	.00787	.00956	.0116	.0138
0.09	.00266	.00328	.00402	.004845	.005800	.006860	.00820	.00995	.0121	.0147	.0174
0.10	.00328	.00405	.00496	.005980	.007170	.008480	.0101	.0123	.0149	.0181	.0215
0.12	.00473	.00583	.00713	.008620	.01032	.01220	.0146	.0177	.0215	.0261	.0310
0.14	.00643	.00794	.00972	.01172	.01404	.01662	.0198	.0241	.0293	.0355	.0422
0.15	.00739	.00912	.01115	.01345	01611	.01910	.0228	.0277	.0336	.0407	.0484
0.16	.00841	.01036	.01268	.01531	.01835	.02170	.0259	.0315	.0382	.0463	.0551
0.18	.01064	.01311	.01605	.01940	.02320	.02745	.0328	.0398	.0484	.0586	.0697
0.20	.01315	.0162	.01983	.02390	.02865	.03390	.0405	.0492	.0597	.0724	.0861
0.25	.020	.0253	.03100	.03740	.04480	.05300	.0632	.0768	.0933	.113	.134
0.30	.0296	.0364	.04460	.05380	.06450	.07630	.0911	.111	.134	.163	.194
0.35	.0403	.0496	.0608	.07330	.08790	.1039	.124	.151	.183	.222	.264
0.40	.0527	.0648	.07940	.09575	.1145	.1355	.162	.197	.239	.290	.344
0.45	.0665	.0820	.1005	.1211	.1450	.1718	.205	.249	.302	.366	.436
0.50	.0822	.1012	.1240	.1495	.1780	.2120	.253	.307	.373	.452	.538
0.55	.0994	.1225	.1500	.1810	.2165	.2565	.306	.372	.452	.547	.651
0.60	.1182	.1458	.1784	.2150	.2580	.3050	.364	.442	.537	.652	.775
0.65	.1390	.1710	.2095	.2530	.3030	.3580	.428	.519	.631	.765	.909
0.70	.1610	.1983	.2430	.2930	.3510	.4155	.496	.602	.732	.887	1.05
0.75	.1850	.2278	.2785	.3365	.4030	.4770	.569	.691	.840	1.02	1.21
0.80	.2105	.2590	.3175	.3825	.4585	.5425	.648	.787	.956	1.16	1.38
0.85	.2375	.2925	.3580	.4325	.5175	.6125	.731	.888	1.08	1.31	1.55
0.90	.2660	.3280	.4018	.4845	.5800	.6860	.820	.995	1.21	1.47	1.74
0.95	.2965	.3650	.4470	.5400	.6460	.7650	.913	1.11	1.35	1.63	1.94
1.00	.3282	.4050	.4960	.5880	.7170	.8480	1.01	1.23	1.49	1.81	2.15
2.00	1.315	1.620	1.983	2.390	2.865	3.390	4.05	4.92	5.97	7.24	8.61
3.00	2.960	3.640	4.460	5.380	6.450	7.630	9.11	11.1	13.4	16.3	19.4
4.00	5.270	6.480	7.940	9.575	11.45	13.55	16.2	19.7	23.9	29.0	34.4
5.00	8.220	10.12	12.40	14.95	17.90	21.20	25.3	30.7	37.3	45.2	53.8

TABLE B - TEMPERATURE CORRECTIONS TO TABLE A.

See below for use of table.

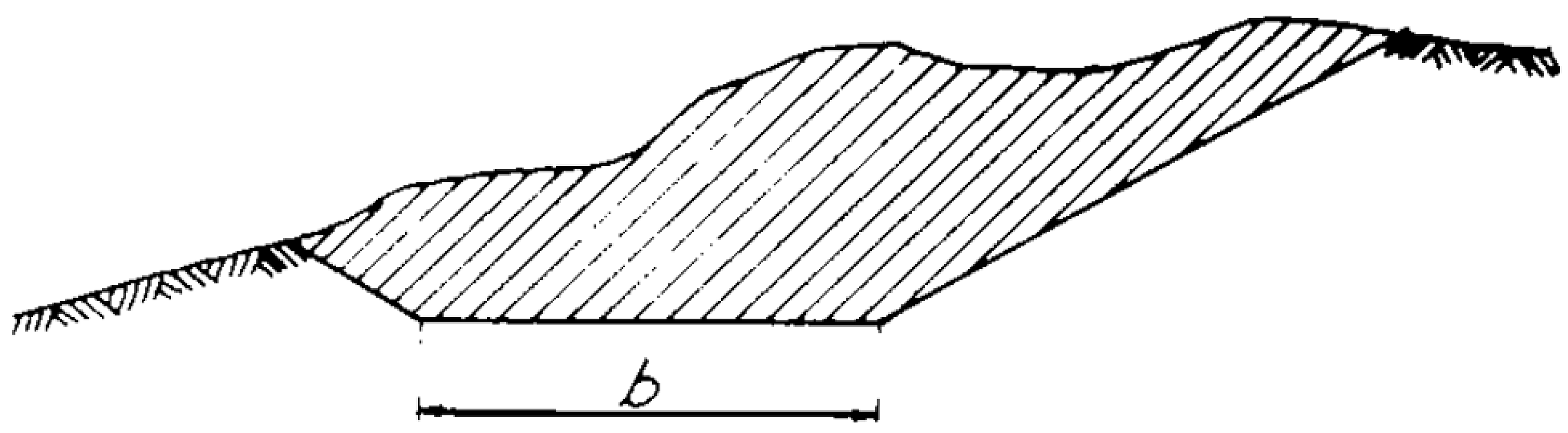
TEMP. IN °F.	t_c
32	0.64
35	.67
40	.73
45	.80
50	.86
55	0.93
60	1.00
65	1.08
70	1.15
75	1.23
80	1.30
85	1.39
90	1.47
95	1.55
100	1.64

Use of Table B:-

If temperature is other than 60°F., multiply k value in Table A by value of t_c opposite applicable temperature in Table B.

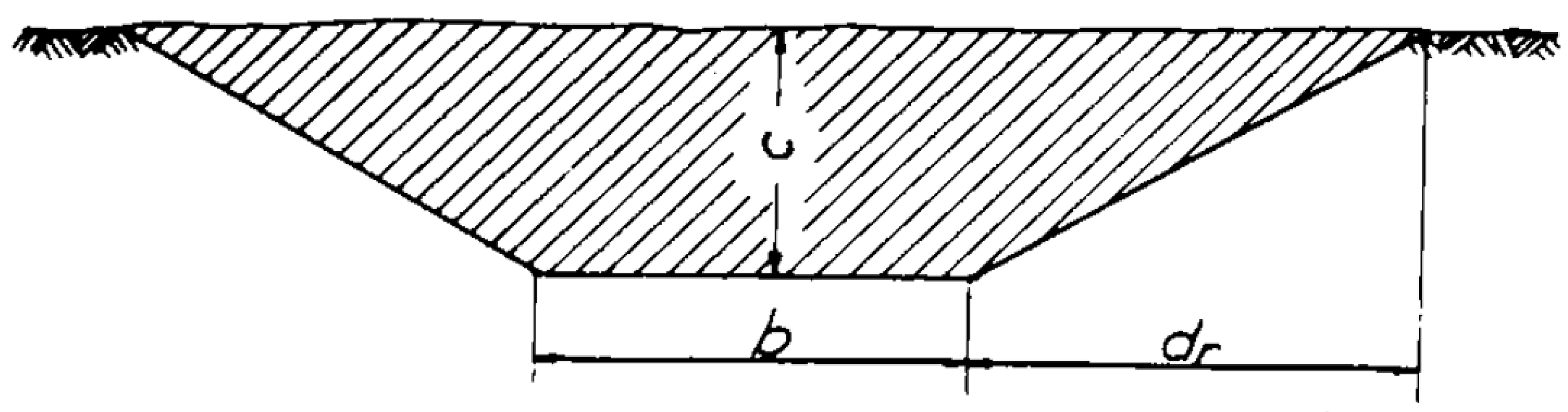
* Adapted from Low Dams by National Resources Committee.

EARTHWORK - COMPUTATIONS



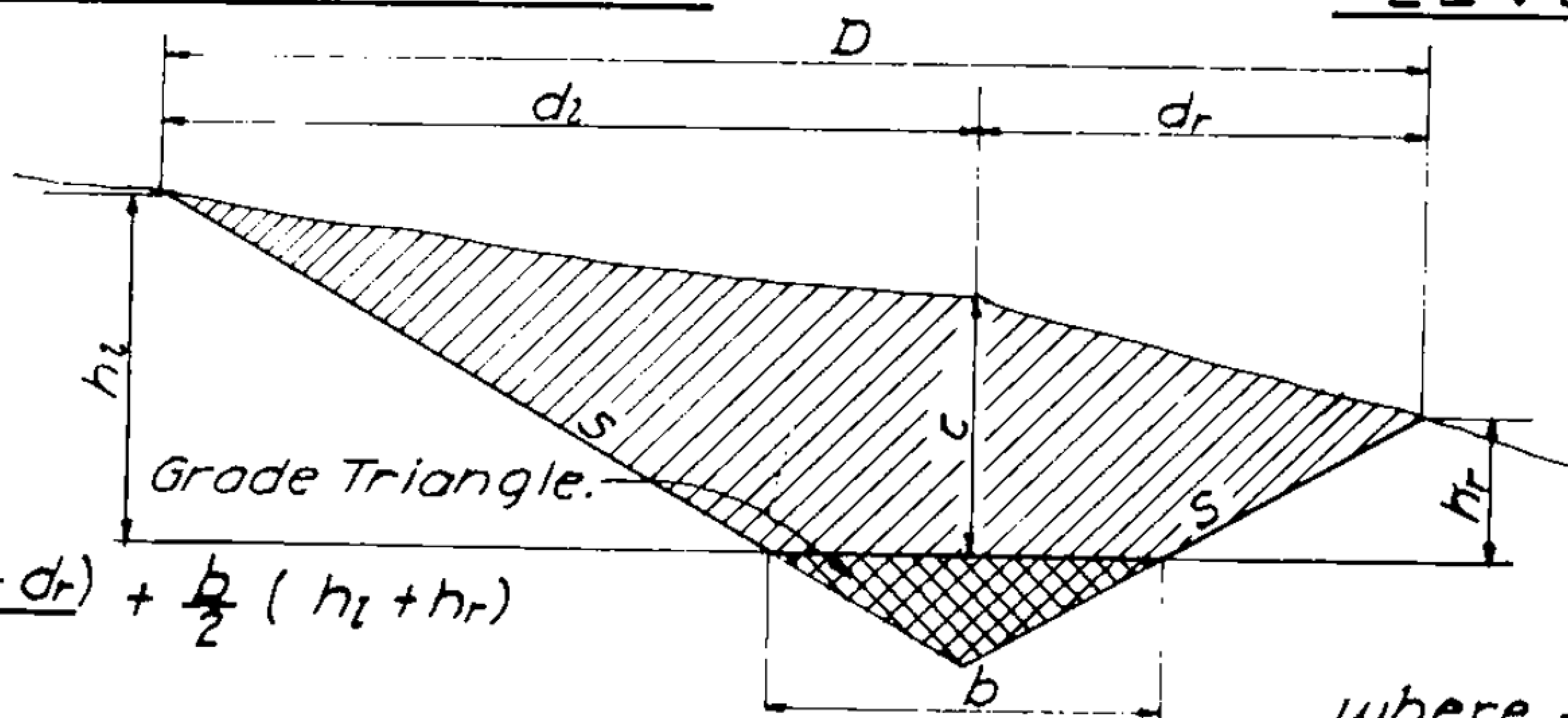
Find area by planimeter or by counting squares on cross section paper.

IRREGULAR SECTIONS.



Area = $c(b + Sc)$, where: $S = \frac{d_r}{c}$ = Slope.

LEVEL SECTIONS.



METHOD I
Area = $\frac{c(d_l + d_r)}{2} + \frac{b}{2}(h_l + h_r)$

METHOD II
Area = $\left(c + \frac{b}{2S}\right) \cdot \frac{D}{2} - \frac{b^2}{4S}$

where $\frac{b^2}{4S}$ = Area of Grade Triangle.

and $S = \frac{d_r - \frac{1}{2}b}{h_r}$

THREE LEVEL SECTIONS.

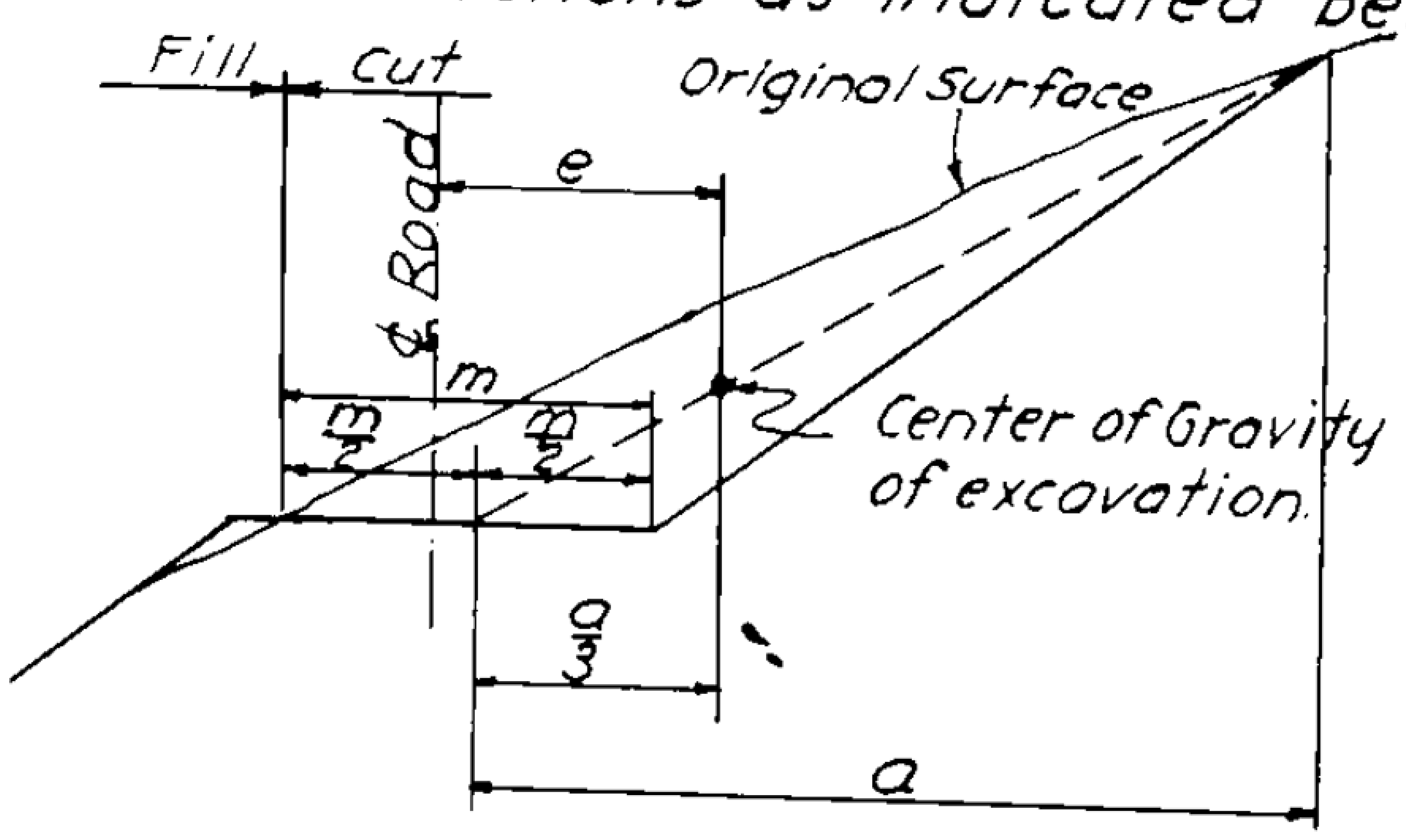
FIG. A - METHODS OF FINDING AREAS.

1. By Average End Areas*: Volume in cubic yards = $\frac{A_0 + A_1}{2} \cdot \frac{l}{27}$ where l = distance in feet between section A_0 and A_1. Compute end areas as indicated in Fig. A above. Use Table A, pg. 3-31 & 32, also see example page 3-31.

2. By Prismoidal Formula: Volume in cubic yards = $\frac{A_0 + 4M + A_1}{6} \cdot \frac{l}{27}$, where l = distance in feet between sections A_0 and A_1, M = area at section midway between section A_0 and A_1.

3. Using Prismoidal Corrections: Subtract volume in Table A page 3-33 from volume found using Average End Areas method.

4. To find volume of excavation on curves use average end area method with "l" between sections as indicated below. Fill volumes can be computed similarly.



l = Distance beteen centers of gravity of adjacent sections. Locate c.g. as shown on left - plot "e" on plan and scale "l" along curve as indicated at right.

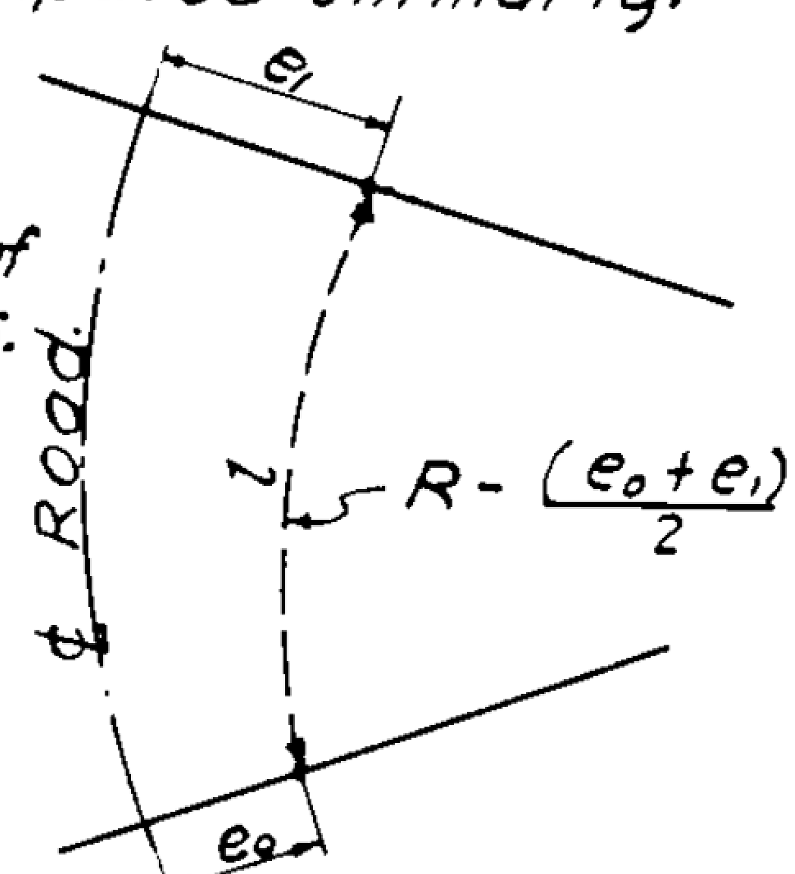


FIG. B - METHODS OF FINDING VOLUMES.

* Used by most State Highway Departments and Public Roads Administration. Recommended for roads and airports.

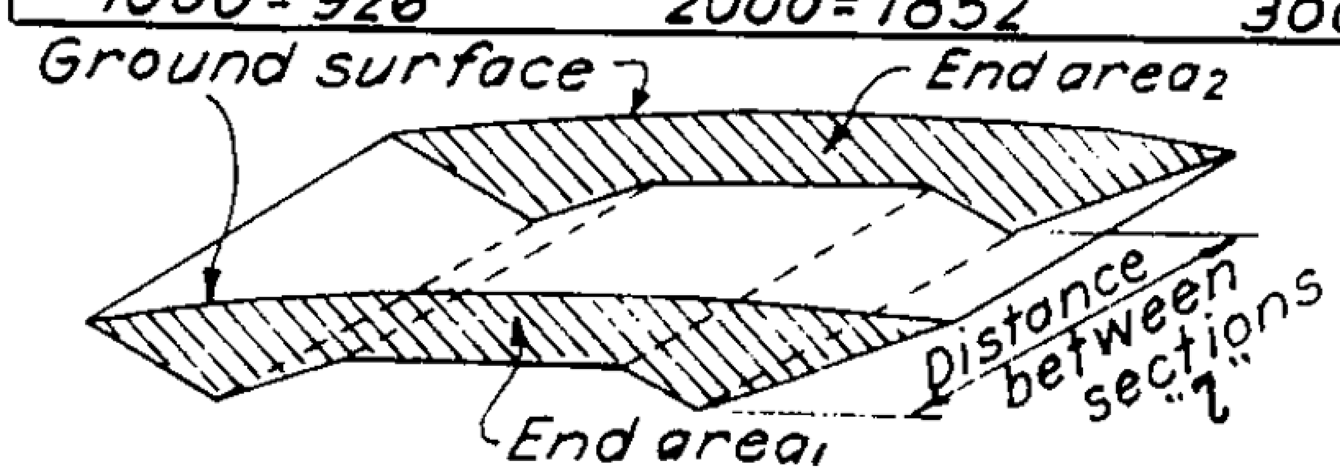
EARTHWORK - DOUBLE END AREA VOLUMES - 1

TABLE A - CUBIC YARDS FOR SUM OF END AREAS FOR DISTANCE BETWEEN STATIONS OF 50 FEET.*

D.A. = Sum of end areas in square feet

D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	DISTANCE BETWEEN SECTIONS	CONSTANT
0	0	50	46	100	93	150	139	200	185	250	231	300	278	350	324	400	370	450	417	0'	.0000
1	1	51	47	101	94	151	140	201	186	251	232	301	279	351	325	401	371	451	418	1'	.0185
2	2	52	48	102	94	152	141	202	187	252	233	302	280	352	326	402	372	452	419	2'	.0370
3	3	53	49	103	95	153	142	203	188	253	234	303	281	353	327	403	373	453	419	3'	.0556
4	4	54	50	104	96	154	143	204	189	254	235	304	281	354	328	404	374	454	420	4'	.0741
5	5	55	51	105	97	155	144	205	190	255	236	305	282	355	329	405	375	455	421	5'	.0926
6	6	56	52	106	98	156	144	206	191	256	237	306	283	356	330	406	376	456	422	6'	.1111
7	7	57	53	107	99	157	145	207	192	257	238	307	284	357	331	407	377	457	423	7'	.1296
8	7	58	54	108	100	158	146	208	193	258	239	308	285	358	331	408	378	458	424	8'	.1482
9	8	59	55	109	101	159	147	209	194	259	240	309	286	359	332	409	379	459	425	9'	.1667
10	9	60	56	110	102	160	148	210	194	260	241	310	287	360	333	410	380	460	426	10'	.1852
11	10	61	56	111	103	161	149	211	195	261	242	311	288	361	334	411	381	461	427	11'	.2037
12	11	62	57	112	104	162	150	212	196	262	243	312	289	362	335	412	381	462	428	12'	.2222
13	12	63	58	113	105	163	151	213	197	263	244	313	290	363	336	413	382	463	429	13'	.2407
14	13	64	59	114	106	164	152	214	198	264	244	314	291	364	337	414	383	464	430	14'	.2593
15	14	65	60	115	106	165	153	215	199	265	245	315	292	365	338	415	384	465	431	15'	.2778
16	15	66	61	116	107	166	154	216	200	266	246	316	293	366	339	416	385	466	431	16'	.2963
17	16	67	62	117	108	167	155	**217**	**201**	267	247	317	294	367	340	417	386	467	432	17'	.3148
18	17	68	63	118	109	168	156	218	202	268	248	318	294	368	341	418	387	468	433	18'	.3333
19	18	69	64	119	110	169	156	219	203	269	249	319	295	369	342	419	388	469	434	19'	.3519
20	19	70	65	120	111	170	157	220	204	270	250	320	296	370	343	420	389	470	435	20'	.3704
21	19	71	66	121	112	171	158	221	205	271	251	321	297	371	344	421	390	471	436	21'	.3889
22	20	72	67	122	113	172	159	222	206	272	252	322	298	372	344	422	391	472	437	22'	.4074
23	21	73	68	123	114	173	160	223	206	273	253	323	299	373	345	423	392	473	438	23'	.4259
24	22	74	69	124	115	174	161	224	207	274	254	324	300	374	346	424	393	474	439	24'	.4445
25	23	75	69	125	116	175	162	225	208	275	255	325	301	375	347	425	394	475	440	25'	.4630
26	24	76	70	126	117	176	163	226	209	276	256	326	302	376	348	426	394	476	441	26'	.4815
27	25	77	71	127	118	177	164	227	210	277	256	327	303	377	349	427	395	477	442	27'	.5000
28	26	78	72	128	119	178	165	228	211	278	257	328	304	378	350	428	396	478	443	28'	.5185
29	27	79	73	129	119	179	166	229	212	279	258	329	305	379	351	429	397	479	444	29'	.5370
30	28	80	74	130	120	180	167	230	213	280	259	330	306	380	352	430	398	480	444	30'	.5556
31	29	81	75	131	121	181	168	231	214	281	260	331	306	381	353	431	399	481	445	31'	.5741
32	30	82	76	132	122	182	169	232	215	282	261	332	307	382	354	432	400	482	446	32'	.5926
33	31	83	77	133	123	183	169	233	216	283	262	333	308	383	355	433	401	483	447	33'	.6111
34	31	84	78	134	124	184	170	234	217	284	263	334	309	384	356	434	402	484	448	34'	.6296
35	32	85	79	135	125	185	171	235	218	285	264	335	310	385	356	435	403	485	449	35'	.6482
36	33	86	80	136	126	186	172	236	219	286	265	336	311	386	357	436	404	486	450	36'	.6667
37	34	87	81	137	127	187	173	237	219	287	266	337	312	387	358	437	405	487	451	**37'**	**.6852**
38	35	88	81	138	128	188	174	238	220	288	267	338	313	388	359	438	406	488	452	38'	.7037
39	36	89	82	139	129	189	175	239	221	289	268	339	314	389	360	439	406	489	453	39'	.7222
40	37	90	83	140	130	190	176	240	222	290	269	340	315	390	361	440	407	490	454	40'	.7408
41	38	91	84	141	131	191	177	241	223	291	269	341	316	391	362	441	408	491	455	41'	.7593
42	39	92	85	142	131	192	178	242	224	292	270	342	317	392	363	442	409	492	456	42'	.7778
43	40	93	86	143	132	193	179	243	225	293	271	343	318	393	364	443	410	493	456	43'	.7963
44	41	94	87	144	133	194	180	244	226	294	272	344	319	394	365	444	411	494	457	44'	.8148
45	42	95	88	145	134	195	181	245	227	295	273	345	319	395	366	445	412	495	458	45'	.8333
46	43	96	89	146	135	196	181	246	228	296	274	346	320	396	367	446	413	496	459	46'	.8519
47	44	97	90	147	136	197	182	247	229	297	275	347	321	397	368	447	414	497	460	47'	.8704
48	44	98	91	148	137	198	183	248	230	298	276	348	322	398	369	448	415	498	461	48'	.8889
49	45	99	92	149	138	199	184	249	231	299	277	349	323	399	369	449	416	499	462	49'	.9074
50	46	100	93	150	139	200	185	250	231	300	278	350	324	400	370	450	417	**500**	**463**	50'	.9259

1000 = 926   2000 = 1852   3000 = 2778   4000 = 3704   5000 = 4630



Example 1.- Given: End Area₁ = 97 sq.ft. End Area₂ = 120 sq.ft., l = 50'. Required: Cubic yards between sections. Solution: D.A. = 97 + 120 = 217 sq.ft. Enter D.A. column and to right of 217 find C.Y. = 201 in C.Y. column.

Use Table A - page 3-32 for D.A. of from 500 to 1000 cu.yds.

Example 2: Given - D.A. = 2751 sq.ft., l = 50'. Required: Cubic yards between stations. Solution - D.A. of 2000 = 1852 cu.yds. - Find at bottom of Table A p. 3-32 ; D.A. of 751 sq.ft = 695 cu.yd. Therefore cubic yards for D.A. of 2751 sq.ft = 1852 + 695 = 2547 Cubic yards.

Example 3: When "l" is less than 50'. Given: D.A. = 217 sq.ft., l = 37'. Required: C.Y. between sections. Solution: Enter column "Distance between Sections" and to right of 37 find "Constant" .6852. Then .6852 x 217 = 149 C.Y.

* Based on average end area formula. Not as accurate as prismoidal formula, but as accurate as usual field measurements warrant. Specified for payment quantities by most State Highway Depts.

EARTHWORK - DOUBLE END AREA VOLUMES-2

TABLE A - CUBIC YARDS FOR SUM OF END AREAS FOR DISTANCE BETWEEN STATIONS OF 50 FEET.*

D.A. = Sum of end areas in square feet. (Double End Area)

D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	D.A.	C.Y.	DISTANCE BETWEEN SECTIONS	CONSTANT
500	463	550	509	600	556	650	602	700	648	750	694	800	741	850	787	900	833	950	880	1	0.0185
501	464	551	510	601	556	651	603	701	649	751	695	801	742	851	788	901	834	951	881	2	0.0370
502	465	552	511	602	557	652	604	702	650	752	696	802	743	852	789	902	835	952	881	3	0.0556
503	466	553	512	603	558	653	605	703	651	753	697	803	744	853	790	903	836	953	882	4	0.0741
504	467	554	513	604	559	654	606	704	652	754	698	804	744	854	791	904	837	954	883	5	0.0926
505	468	555	514	605	560	655	606	705	653	755	699	805	745	855	792	905	838	955	884	6	0.1111
506	469	556	515	606	561	656	607	706	654	756	700	806	746	856	793	906	839	956	885	7	0.1296
507	469	557	516	607	562	657	608	707	655	757	701	807	747	857	794	907	840	957	886	8	0.1482
508	470	558	517	608	563	658	609	708	656	758	702	808	748	858	794	908	841	958	887	9	0.1667
509	471	559	518	609	564	659	610	709	656	759	703	809	749	859	795	909	842	959	888	10	0.1852
510	472	560	519	610	565	660	611	710	657	760	704	810	750	860	796	910	843	960	889	11	0.2037
511	473	561	519	611	566	661	612	711	658	761	705	811	751	861	797	911	844	961	890	12	0.2222
512	474	562	520	612	567	662	613	712	659	762	706	812	752	862	798	912	844	962	891	13	0.2407
513	475	563	521	613	568	663	614	713	660	763	706	813	753	863	799	913	845	963	892	14	0.2593
514	476	564	522	614	569	664	615	714	661	764	707	814	754	864	800	914	846	964	893	15	0.2778
515	477	565	523	615	569	665	616	715	662	765	708	815	755	865	801	915	847	965	894	16	0.2963
516	478	566	524	616	570	666	617	716	663	766	709	816	756	866	802	916	848	966	894	17	0.3148
517	479	567	525	617	571	667	618	717	664	767	710	817	756	867	803	917	849	967	895	18	0.3333
518	480	568	526	618	572	668	619	718	665	768	711	818	757	868	804	918	850	968	896	19	0.3519
519	481	569	527	619	573	669	619	719	666	769	712	819	758	869	805	919	851	969	897	20	0.3704
520	481	570	528	620	574	670	620	720	667	770	713	820	759	870	806	920	852	970	898	21	0.3889
521	482	571	529	621	575	671	621	721	668	771	714	821	760	871	806	921	853	971	899	22	0.4074
522	483	572	530	622	576	672	622	722	669	772	715	822	761	872	807	922	854	972	900	23	0.4259
523	484	573	531	623	577	673	623	723	669	773	716	823	762	873	808	923	855	973	901	24	0.4445
524	485	574	531	624	578	674	624	724	670	774	717	824	763	874	809	924	856	974	902	25	0.4630
525	486	575	532	625	579	675	625	725	671	775	718	825	764	875	810	925	856	975	903	26	0.4815
526	487	576	533	626	580	676	626	726	672	776	719	826	765	876	811	926	857	976	904	27	0.5000
527	488	577	534	627	581	677	627	727	673	777	719	827	766	877	812	927	858	977	905	28	0.5185
528	489	578	535	628	581	678	628	728	674	778	720	828	767	878	813	928	859	978	906	29	0.5370
529	490	579	536	629	582	679	629	729	675	779	721	829	768	879	814	929	860	979	906	30	0.5556
530	491	580	537	630	583	680	630	730	676	780	722	830	769	880	815	930	861	980	907	31	0.5741
531	492	581	538	631	584	681	631	731	677	781	723	831	769	881	816	931	862	981	908	32	0.5926
532	493	582	539	632	585	682	631	732	678	782	724	832	770	882	817	932	863	982	909	33	0.6111
533	494	583	540	633	586	683	632	733	679	783	725	833	771	883	818	933	864	983	910	34	0.6296
534	494	584	541	634	587	684	633	734	680	784	726	834	772	884	819	934	865	984	911	35	0.6482
535	495	585	542	635	588	685	634	735	681	785	727	835	773	885	819	935	866	985	912	36	0.6667
536	496	586	543	636	589	686	635	736	681	786	728	836	774	886	820	936	867	986	913	37	0.6852
537	497	587	544	637	590	687	636	737	682	787	729	837	775	887	821	937	868	987	914	38	0.7037
538	498	588	544	638	591	688	637	738	683	788	730	838	776	888	822	938	869	988	915	39	0.7222
539	499	589	545	639	592	689	638	739	684	789	731	839	777	889	823	939	869	989	916	40	0.7408
540	500	590	546	640	593	690	639	740	685	790	731	840	778	890	824	940	870	990	917	41	0.7593
541	501	591	547	641	593	691	640	741	686	791	732	841	779	891	825	941	871	991	918	42	0.7778
542	502	592	548	642	594	692	641	742	687	792	733	842	780	892	826	942	872	992	919	43	0.7963
543	503	593	549	643	595	693	642	743	688	793	734	843	781	893	827	943	873	993	919	44	0.8148
544	504	594	550	644	596	694	643	744	689	794	735	844	781	894	828	944	874	994	920	45	0.8333
545	505	595	551	645	597	695	644	745	690	795	736	845	782	895	829	945	875	995	921	46	0.8519
546	506	596	552	646	598	696	644	746	691	796	737	846	783	896	830	946	876	996	922	47	0.8704
547	506	597	553	647	599	697	645	747	692	797	738	847	784	897	831	947	877	997	923	48	0.8889
548	507	598	554	648	600	698	646	748	693	798	739	848	785	898	831	948	878	998	924	49	0.9074
549	508	599	555	649	601	699	647	749	694	799	740	849	786	899	832	949	879	999	925	50	0.9259

1000 = 926 | 2000 = 1852 | 3000 = 2778 | 4000 = 3704 | 5000 = 4630 | 6000 = 5556 | 7000 = 6481 | 8000 = 7407

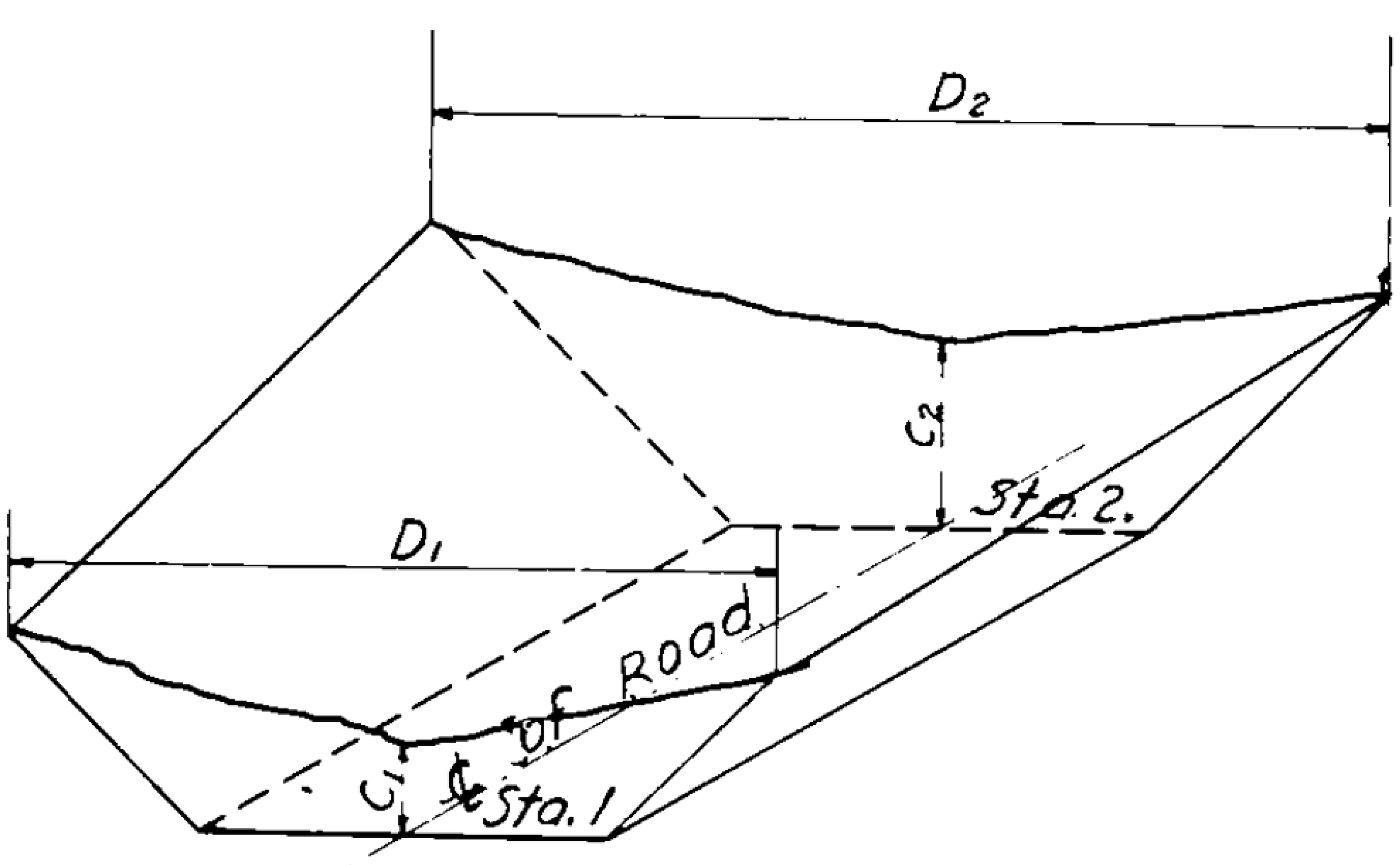
* Based on average end area formula. Not as accurate as prismoidal, but as accurate as usual field measurements warrant. Specified for payment quantities by most State H'way Depts.

For examples illustrating use of table see page 3-31.

EARTHWORK - PRISMOIDAL CORRECTIONS

TABLE A - PRISMOIDAL CORRECTIONS FOR L = 100' STATIONS.*

$D_1 - D_2$ \ $c_1 - c_2 =$	1	2	3	4	5	6	7	8	9
0.1	0.03	0.06	0.09	0.12	0.15	0.19	0.22	0.25	0.28
0.2	0.06	0.12	0.19	0.25	0.31	0.37	0.43	0.49	0.56
0.3	0.09	0.19	0.28	0.37	0.46	0.56	0.65	0.74	0.83
0.4	0.12	0.25	0.37	0.49	0.62	0.74	0.86	0.99	1.11
0.5	0.15	0.31	0.46	0.62	0.77	0.93	1.08	1.23	1.39
0.6	0.19	0.37	0.56	0.74	0.93	1.11	1.30	1.48	1.67
0.7	0.22	0.43	0.65	0.86	1.08	1.30	1.51	1.73	1.94
0.8	0.25	0.49	0.74	0.99	1.23	1.48	1.73	1.98	2.22
0.9	0.28	0.56	0.83	1.11	1.39	1.67	1.94	2.22	2.50
1.0	0.31	0.62	0.93	1.23	1.54	1.85	2.16	2.47	2.78
1.1	0.34	0.68	1.02	1.36	1.70	2.04	2.38	2.72	3.06
1.2	0.37	0.74	1.11	1.48	1.85	2.22	2.59	2.96	3.33
1.3	0.40	0.80	1.20	1.60	2.01	2.41	2.81	3.21	3.61
1.4	0.43	0.86	1.30	1.73	2.16	2.59	3.02	3.46	3.89
1.5	0.46	0.93	1.39	1.85	2.31	2.78	3.24	3.70	4.17
1.6	0.49	0.99	1.48	1.98	2.47	2.96	3.46	3.95	4.44
1.7	0.52	1.05	1.57	2.10	2.62	3.15	3.67	4.20	4.72
1.8	0.56	1.11	1.67	2.22	2.78	3.33	3.89	4.44	5.00
1.9	0.59	1.17	1.76	2.35	2.93	3.52	4.10	4.69	5.28
2.0	0.62	1.23	1.85	2.47	3.09	3.70	4.32	4.94	5.56
2.1	0.65	1.30	1.94	2.59	3.24	3.89	4.54	5.19	5.83
2.2	0.68	1.36	2.04	2.72	3.40	4.07	4.75	5.43	6.11
2.3	0.71	1.42	2.13	2.84	3.55	4.26	4.97	5.68	6.39
2.4	0.74	1.48	2.22	2.96	3.70	4.44	5.19	5.93	6.67
2.5	0.77	1.54	2.31	3.09	3.86	4.63	5.40	6.17	6.94
2.6	0.80	1.60	2.41	3.21	4.01	4.81	5.62	6.42	7.22
2.7	0.83	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50
2.8	0.86	1.73	2.59	3.46	4.32	5.19	6.05	6.91	7.78
2.9	0.90	1.79	2.69	3.58	4.48	5.37	6.27	7.16	8.06
3.0	0.93	1.85	2.78	3.70	4.63	5.56	6.48	7.41	8.33
3.1	0.96	1.91	2.87	3.83	4.78	5.74	6.70	7.65	8.61
3.2	0.99	1.98	2.96	3.95	4.94	5.93	6.91	7.90	8.89
3.3	1.02	2.04	3.06	4.07	5.09	6.11	7.13	8.15	9.17
3.4	1.05	2.10	3.15	4.20	5.25	6.30	7.35	8.40	9.44
3.5	1.08	2.16	3.24	4.32	5.40	6.48	7.56	8.64	9.72
3.6	1.11	2.22	3.33	4.44	5.56	6.67	7.78	8.89	10.00
3.7	1.14	2.28	3.43	4.57	5.71	6.85	7.99	9.14	10.28
3.8	1.17	2.35	3.52	4.69	5.86	7.04	8.21	9.38	10.56
3.9	1.20	2.41	3.61	4.81	6.02	7.22	8.43	9.63	10.83
4.0	1.23	2.47	3.70	4.94	6.17	7.41	8.64	9.88	11.11
4.1	1.27	2.53	3.80	5.06	6.33	7.59	8.86	10.12	11.39
4.2	1.30	2.59	3.89	5.19	6.48	7.78	9.07	10.37	11.67
4.3	1.33	2.65	3.98	5.31	6.64	7.96	9.29	10.62	11.94
4.4	1.36	2.72	4.07	5.43	6.79	8.15	9.51	10.86	12.22
4.5	1.39	2.78	4.17	5.56	6.94	8.33	9.72	11.11	12.50
4.6	1.42	2.84	4.26	5.68	7.10	8.52	9.94	11.36	12.78
4.7	1.45	2.90	4.35	5.80	7.25	8.70	10.15	11.60	13.06
4.8	1.48	2.96	4.44	5.93	7.41	8.89	10.37	11.85	13.33
4.9	1.51	3.02	4.54	6.05	7.56	9.07	10.50	12.10	13.61
5.0	1.54	3.09	4.63	6.17	7.72	9.26	10.80	12.35	13.89
5.1	1.57	3.15	4.72	6.30	7.87	9.44	11.02	12.59	14.17
5.2	1.60	3.21	4.81	6.42	8.02	9.63	11.23	12.84	14.44
5.3	1.64	3.27	4.91	6.54	8.18	9.81	11.45	13.09	14.72
5.4	1.67	3.33	5.00	6.67	8.33	10.00	11.67	13.33	15.00
5.5	1.70	3.40	5.09	6.79	8.49	10.19	11.88	13.58	15.28
5.6	1.73	3.46	5.19	6.91	8.64	10.37	12.10	13.83	15.56
5.7	1.76	3.52	5.28	7.04	8.80	10.56	12.31	14.07	15.83
5.8	1.79	3.58	5.37	7.16	8.95	10.74	12.53	14.32	16.11
5.9	1.82	3.64	5.46	7.28	9.10	10.93	12.75	14.57	16.39
6.0	1.85	3.70	5.56	7.41	9.26	11.11	12.96	14.81	16.67
6.1	1.88	3.77	5.65	7.53	9.41	11.30	13.18	15.06	16.94
6.2	1.91	3.83	5.74	7.65	9.57	11.48	13.40	15.31	17.22
6.3	1.94	3.89	5.83	7.78	9.72	11.67	13.61	15.56	17.50
6.4	1.98	3.95	5.93	7.90	9.88	11.85	13.83	15.80	17.78
6.5	2.01	4.01	6.02	8.02	10.03	12.04	14.04	16.05	18.06
6.6	2.04	4.07	6.11	8.15	10.19	12.22	14.26	16.30	18.33
6.7	2.07	4.14	6.20	8.27	10.34	12.41	14.48	16.54	18.61
6.8	2.10	4.20	6.30	8.40	10.49	12.59	14.69	16.79	18.89
6.9	2.13	4.26	6.39	8.52	10.65	12.78	14.91	17.04	19.17
7.0	2.16	4.32	6.48	8.64	10.80	12.96	15.12	17.28	19.44
7.1	2.19	4.38	6.57	8.77	10.96	13.15	15.34	17.53	19.72
7.2	2.22	4.44	6.67	8.89	11.11	13.33	15.56	17.78	20.00
7.3	2.25	4.51	6.76	9.01	11.27	13.52	15.77	18.02	20.28
7.4	2.28	4.57	6.85	9.14	11.42	13.70	15.99	18.27	20.56
7.5	2.31	4.63	6.94	9.26	11.57	13.89	16.20	18.52	20.83
7.6	2.35	4.69	7.04	9.38	11.73	14.07	16.42	18.77	21.11
7.7	2.38	4.75	7.13	9.51	11.88	14.26	16.64	19.01	21.39
7.8	2.41	4.81	7.22	9.63	12.04	14.44	16.85	19.26	21.67
7.9	2.44	4.88	7.31	9.75	12.19	14.63	17.07	19.51	21.94
8.0	2.47	4.94	7.41	$\boxed{9.88}$	12.35	14.81	17.28	19.75	22.22
8.1	2.50	5.00	7.50	10.00	12.50	15.00	17.50	20.00	22.50
8.2	2.53	5.06	7.59	10.12	12.65	15.19	17.72	20.25	22.78
8.3	2.56	5.12	7.69	10.25	12.81	15.37	17.93	20.49	23.06
8.4	2.59	5.19	7.78	10.37	12.96	15.56	18.15	20.74	23.33
8.5	2.62	5.25	7.87	10.49	13.12	15.74	18.36	20.99	23.61
8.6	2.65	5.31	7.96	10.62	13.27	15.93	18.58	21.23	23.89
8.7	2.69	5.37	8.06	10.74	13.43	16.11	18.80	21.48	24.17
8.8	2.72	5.43	8.15	10.86	13.58	16.30	19.01	21.73	24.44
8.9	2.75	5.49	8.24	10.99	13.73	16.48	19.23	21.97	24.72
9.0	2.78	5.56	8.33	11.11	13.89	16.67	19.44	22.22	25.00
9.1	2.81	5.62	8.43	11.23	14.04	16.85	19.66	22.47	25.28
9.2	2.84	5.68	8.52	11.36	14.20	17.04	19.88	22.72	25.56
9.3	2.87	5.74	8.61	11.48	14.35	17.22	20.09	22.96	25.83
9.4	2.90	5.80	8.70	11.60	14.51	17.41	20.31	23.21	26.11
9.5	2.93	5.86	8.80	11.73	14.66	17.59	20.52	23.46	26.39
9.6	2.96	5.93	8.89	11.85	14.81	17.78	20.74	23.70	26.67
9.7	2.99	5.99	8.98	11.98	14.97	17.96	20.96	23.95	26.94
9.8	3.02	6.05	9.07	12.10	15.12	18.15	21.17	24.20	27.22
9.9	3.06	6.11	9.17	12.22	15.28	18.33	21.39	24.44	27.50
10.0	3.09	6.17	9.26	12.35	15.43	18.52	21.60	24.69	27.78



$c_1, c_2, D_1, \& D_2$ are shown for a three level section. Volume by Average End Area ± Prismoidal Correction = Volume by Prismoidal Formula.
When $(c_2-c_1)(D_2-D_1)$ is +, subtract correction.
When $(c_2-c_1)(D_2-D_1)$ is −, add correction.

Irregular Sections are generally treated the same as three level sections.

Example: Given: $C_1 = 4'$, $D_1 = 130'$, $C_2 = 8'$, $D_2 = 138'$. Required: Prismoidal Correction Value. Solution: $c_1 - c_2 = 4$; $D_1 - D_2 = 8$. Enter table as indicated; read correction = 9.88 cu. yds. $(C_2-C_1)(D_2-D_1) = (8-4)(138-130) = +$. Subtract Correction from volume by Aver. End Area Method. See Pg. 3-31.

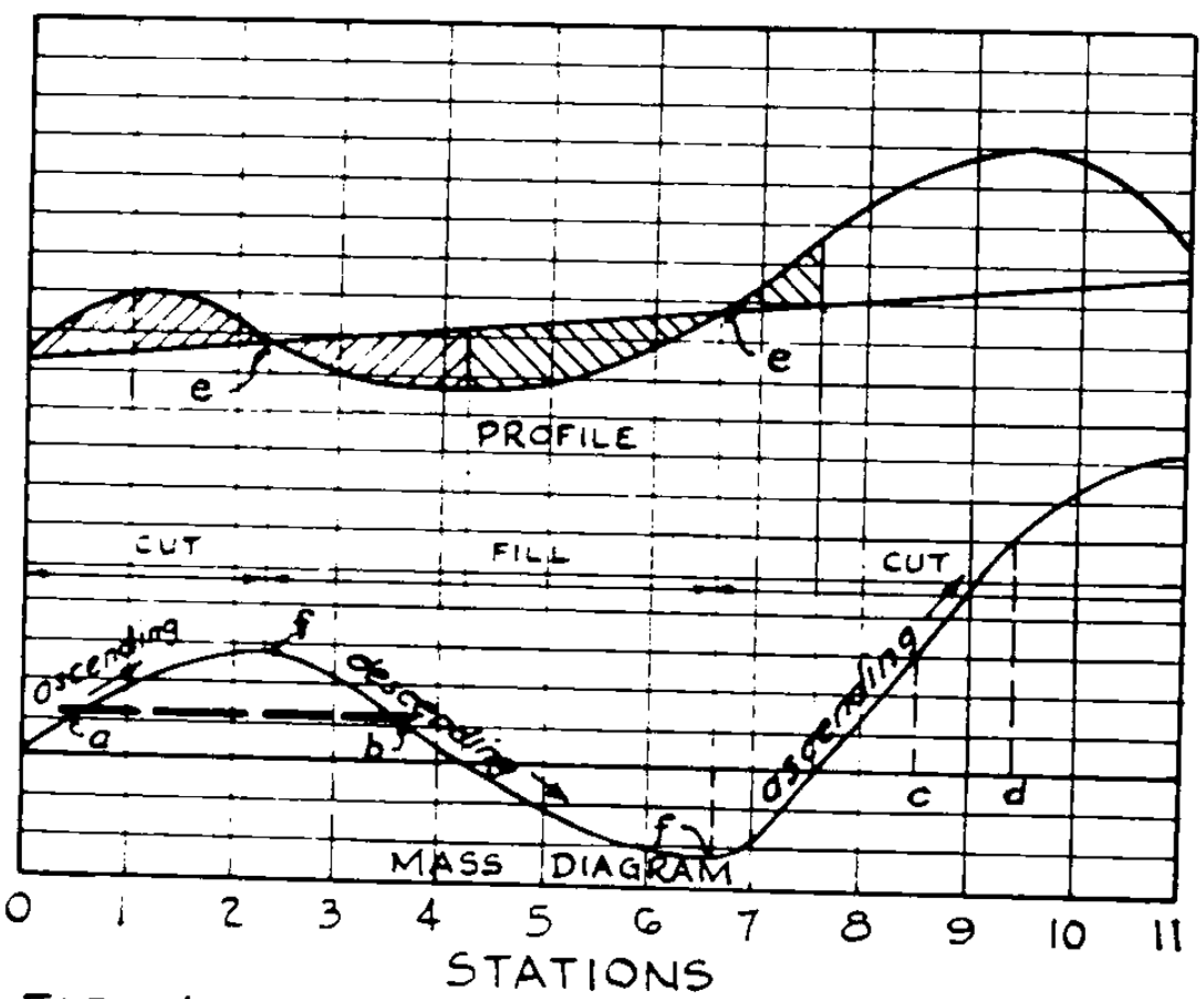
*Adapted from American Civil Engineers Handbook by Merriman & Wiggin.

EARTHWORK – MASS DIAGRAM

A MASS DIAGRAM is a graphical solution of movement of earth, or "haul", plotted on cross-section paper above or below a profile of a road or railroad at the same horizontal scale, with stations on the profile projected on the diagram. Each station is assumed to be the center of gravity of a volume of earth extending 50' on either side, and the volumes for the stations are first computed, - cut being plus and fill minus. Ordinates of the mass diagram are cumulative algebraic sums of station volumes from the point of beginning. At stations in fill it is customary to make an allowance for shrinkage of earth or swelling of ledge rock which is computed as a percentage of the material involved and added algebraically to the ordinate. Ordinates at station points are connected by a smooth curve, completing the mass diagram.

A MASS DIAGRAM is used –

(a) to determine volume, location and distances of haul and "overhaul" and thus estimate cost of earth movement.
(b) to plan earthwork economically with respect to disposition of fill, location of borrow and waste, limits of profitable haul and points where borrow and waste are economical.
(c) to determine the most efficient type of construction equipment.
(d) to balance cut and fill in design of vertical alignment. This balance should be secondary compared to a finished design with recommended grades, alignments, clearances, widths, etc.



MASS DIAGRAM COMPUTATION				
STATION	THEORETICAL VOLUME		FILLS PLUS SHRINKAGE All. (15%)	MASS DIAGRAM ORDINATE
	CUT	FILL		
0				0
1	+ 182			+ 182
2	+ 78			+ 260
3		- 84	- 97	+ 163
4		- 123	- 141	+ 22
5		- 107	- 123	- 101
6		- 92	- 106	- 207
7	+ 64			- 143
8	+ 251			+ 108
9	+ 332			+ 440
10	+ 287			+ 727
11	+ 76			+ 803

FIG. A - EXAMPLE OF MASS DIAGRAM CONSTRUCTION.

Note: Shrinkage allowance of 15 % used in above computation.

PROPERTIES OF MASS DIAGRAM

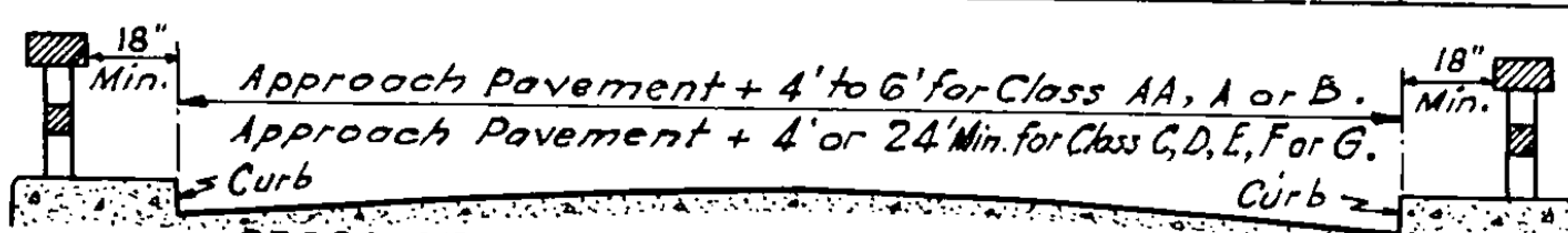
(1) Ascending curves denote excavation and descending curves embankment.
(2) Between any two stations such as "a" & "b" where the curve is intersected by a horizontal line, excavation equals embankment.
(3) The area cut off by this horizontal line and the curve is the measure of the haul between the two stations cut by that line, "a" & "b".
(4) The difference in length between any two vertical ordinates of the diagram is the volume between the stations at which the ordinates are erected, such as "c" & "d".
(5) Hill sections in the diagram represent haul forward on the profile, and valley sections haul backward.
(6) Grade points of the profile as at "e" correspond to maximum and minimum points of the mass diagram as at "f".

ROADS - DESIGN CRITERIA & CLASSIFICATION

TABLE A - DESIGN CRITERIA*

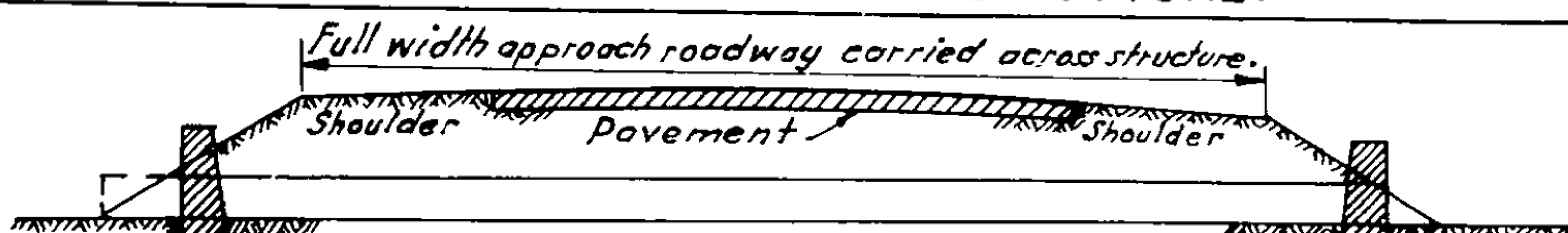
CLASS OF ROAD DAILY TRAFFIC SEE NOTE 1 BELOW.	AA OVER 20,000	A 4,000 TO 20,000	B 750 TO 4,000	C 300 TO 750	D UNDER 300	E, F & G E = 200 MAX. F = 100 " G = 50 "
Surfaced Width.	2 - 36' Pavements	2 - 24' Pavements See Note 2 below	2-11' or 12' Lanes	2-11' or 12' Lanes	2-10' to 12' Lanes	20' Min. 2 Lanes 10' to 14' - 1 Lane
Shoulders.	10' stabilized	10' stabilized	8' to 10' stabilized	6' Minimum 8' Preferred		4' Minimum 8' Preferred.
Minimum Right of Way.	200'	125'	100'	100'	100'	66'
Recommended Design Speed.	60 to 100 M.P.H.		50 to 75 M.P.H.		30 to 60 M.P.H.	
Maximum Horizontal Curve.	3°	3°	4°	5°	6°	8° to 24°
Minim. Sight Dist. See Note 3 below.	1000'	1000'	800'	800'	600'	500'
Maximum Gradient.	3% for trucks or mixed traffic if practicable, 5% or 6% absolute maxim.			6%	6%	7%
Ultimate Pavement.	High type : Rigid Bituminous or Block.			Intermediate or Low Type: Bituminous or Thin Rigid.		Stabilized or Treated.

Clear Width Structures over 20' Span.



CROSS SECTION AT BRIDGE OR STRUCTURE.

Clear Width Structures Under 20' Span.



CROSS SECTION AT CULVERT.

Note 1. This classification is adapted from the A.A.S.H.O. classification of roads with Class AA added for such roads as Thruways, Multi-Lane Parkways, Freeways, Inter-regional Highways, Express Highways, etc. Class AA roads require special study in each case.
Note 2. Three lane roads are not recommended for new construction.
Note 3. Passing sight distance per Table C Pg. 3-60 should be provided as frequently as local conditions will permit.

TABLE B - CLASSIFICATION BY TRAFFIC DENSITY, TRAFFIC CHARACTER & DESIGN SPEED.**

TRAFFIC DENSITY

Traffic density is defined as the average of the probable maximum hourly traffic of several peak days.
The daily traffic is approximately 10 times the maximum hourly traffic.
On important roads the maximum and average daily traffic should be ascertained by traffic studies.

TRAFFIC CHARACTER

"P"	Passenger Predominant.
"T"	Number of trucks abnormally high.
"M"	Mixed traffic.

Class "T" requires wide lanes, wide shoulders, flat grades, high type pavement & stable base.

DESIGN SPEED

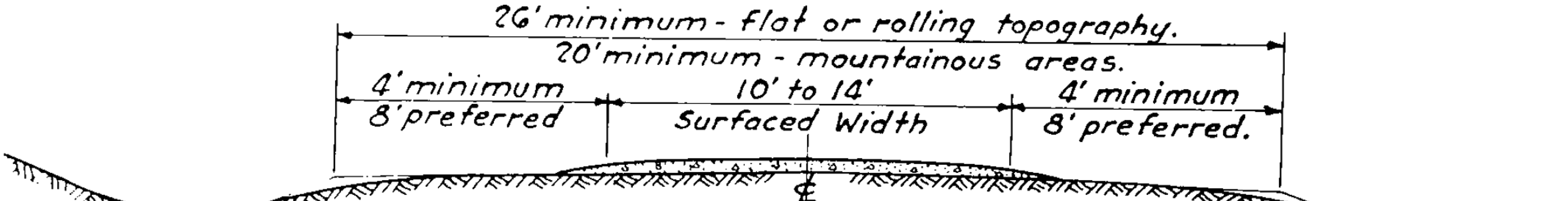
30 miles per hour
40 " " "
50 " " "
60 " " "
70 " " "

Assumed design speed is max. Uniform speed adopted by the faster group of drivers.

Example of A.A.S.H.O. Classification: "1000 M 50" indicates a highway on which 1000 vehicles of mixed traffic are accommodated per hour at an assumed design speed of 50 miles per hour.

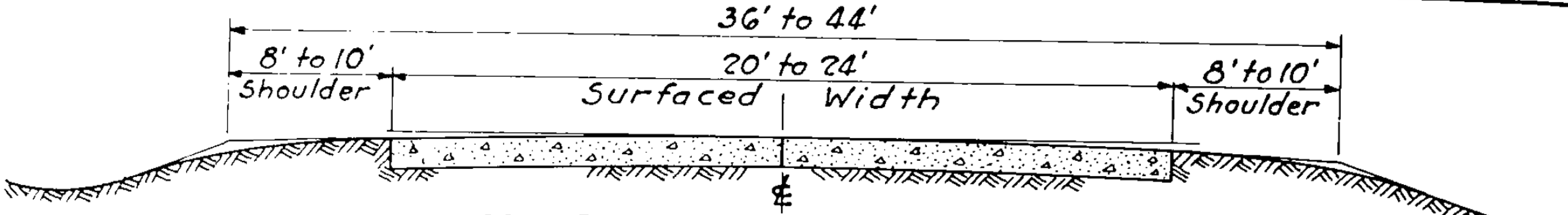
*Design Criteria representative of modern standards as recommended by The Public Roads Admin. (P.R.A.), American Association of State Highway Officials (A.A.S.H.O.), Nat. Inter-regional Highway Comm. and State Highway Departments.
** Adapted from A.A.S.H.O.

ROADS - CLASSIFIED BY TRAFFIC LANES



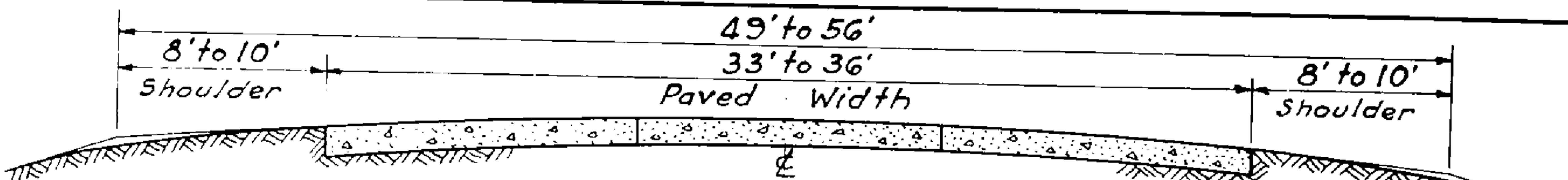
SINGLE LANE HIGHWAY *

Class of Road: "F" and "G" only.



TWO LANE HIGHWAY *

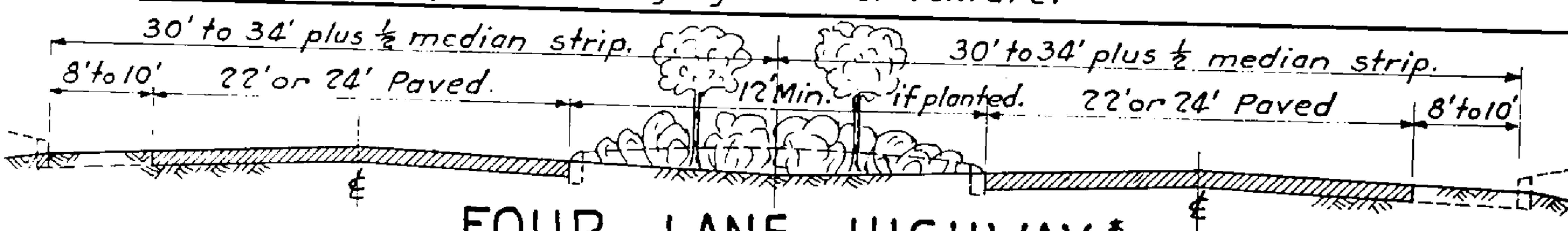
SURFACED WIDTH REQUIRED						
Class of Road	"E" and "D"			"C" and "B"		
Type of Traffic	"P"	"M"	"T"	"P"	"M"	"T"
Speed 30-40 m.p.h.	18'	20'	22'	22'	22'	22'
" 40-60 m.p.h.	20'	20'	22'	22'	22'	24'
" 60-70 m.p.h.	22'	22'	22'	24'	24'	24'



THREE LANE HIGHWAY *

Class of Road: "A" only.

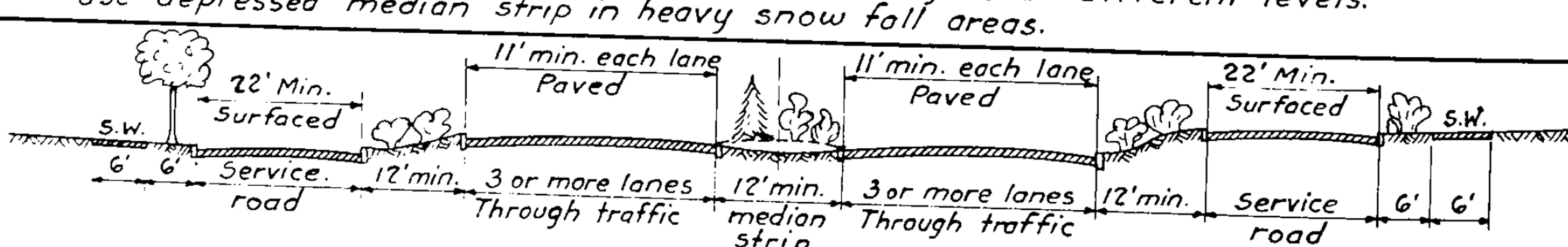
NOTE:-
Construct only where passing sight distance can be obtained at practically all points.
Middle lane preferably contrasting by color or texture.



FOUR LANE HIGHWAY *

Class of Road: "A".

NOTE:-
At bridges and in urban areas median strip may be narrowed to 4' and paved.
Median strips may vary in width and roads may be at different levels.
Use depressed median strip in heavy snow fall areas.



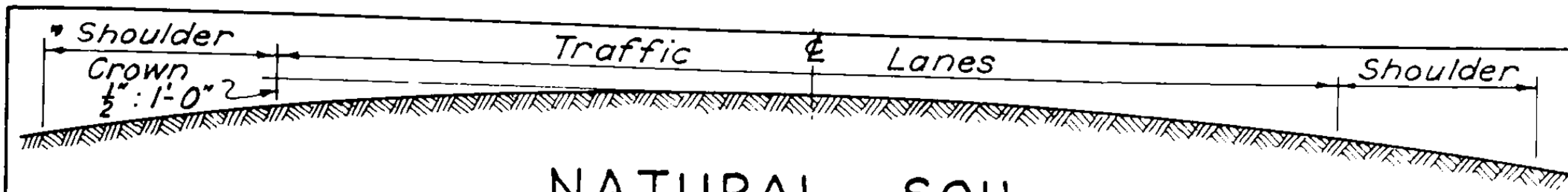
MULTI-LANE PARKWAY

Class of Road: "AA".

Dense traffic in Metropolitan areas. Requires special study for design standards.
Widths may vary and roads may be at same or different levels.

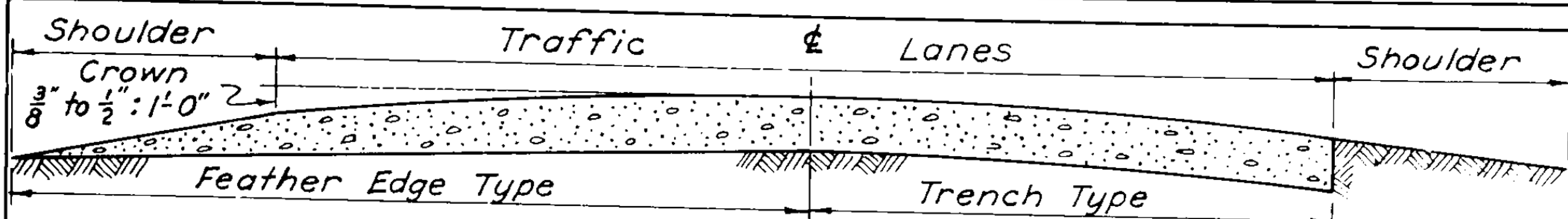
* Adapted from A Policy on Highway Types by A.A.S.H.O.

ROADS - TYPICAL SECTIONS - 1



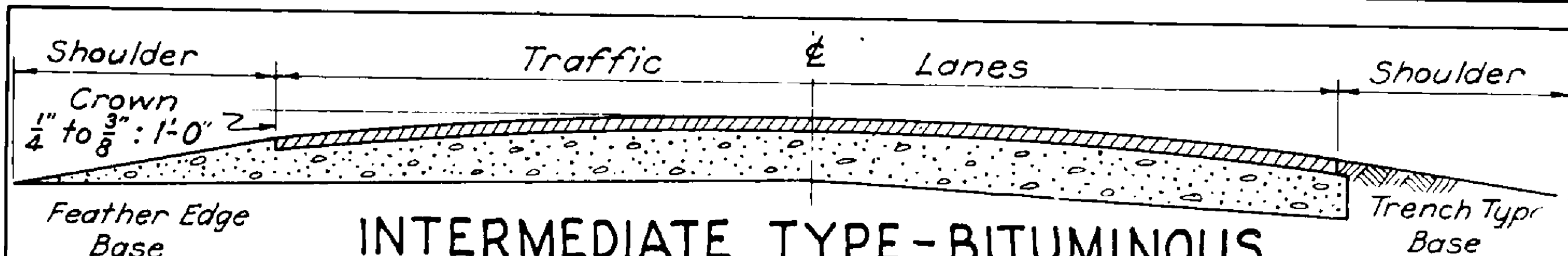
NATURAL SOIL

CLASS OF ROAD	TYPE OF TREATMENT
"F" and "G"	Graded and drained. Crowned ½" per foot and drainage ditches provided.
"E", "F" and "G"	Surface treated with road oil, bitum. material or calcium chloride.
"E", "F" and "G"	1" to 2" of gravel, shells, cinders or stone worked into surface by traffic.
"E", "F" and "G" "SAND CLAY"	Sandy or gravelly soils combined with silty or clay soils and stabilized mechanically.
"E", "F" and "G"	Stabilized with cement, chlorides, asphalts, tars or vinsol resin.



LOW TYPE

CLASS OF ROAD	SURFACE	SURFACE TREATMENT
"C", "D", "E" or "F"	6" of selected soil stabilized with Portland cement, bituminous material or calcium chloride.	Bituminous.
"C", "D", "E" or "F" "SAND CLAY"	6" to 10" of gravel, sand-clay, topsoil, lime-rock, caliche, scoria, shells, chert, shale, slag or cinders.	Road oil, calcium chloride or bituminous.
"C" or "D"	4" to 10" of traffic-bound macadam. 4" to 6" of water-bound macadam.	Bituminous.

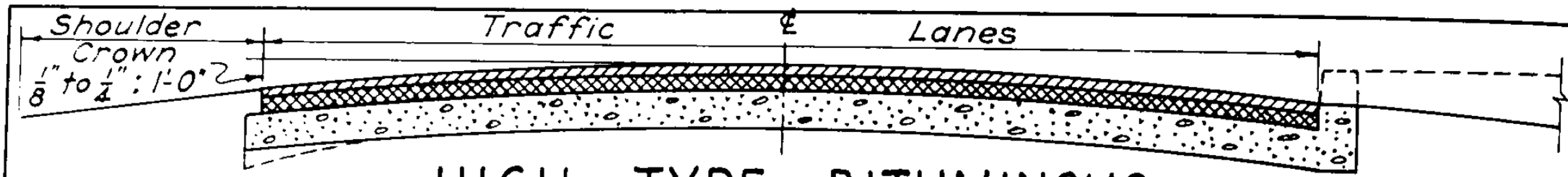


INTERMEDIATE TYPE - BITUMINOUS

CLASS OF ROAD	SURFACE	BASE
"C", "D" and "E"	2½" mixed-in-place (Road-Mix).	6" or more of compacted gravel.
"C" and "D"	2½" low cost plant-mix or pre-mix.	6" crushed gravel or equal.
"B", "C" and "D"	4" to 6" of sand-asphalt.	6" sand-clay or equal.
"B" and "C"	3" bitum. penetration macadam.	3" to 6" crushed stone.
"C" and "D"	1½" bituminous pavement.	6" of stabilized selected soil.
"B" and "C"	1½" to 2½" bituminous pavement.	6" cement-treated base.
"B" and "C"	1½" natural rock asphalt.	6" to 8" water-bound macadam.
"B" and "C"	2½" bitum. penetration macadam.	8" Telford, broken stone, field stone.

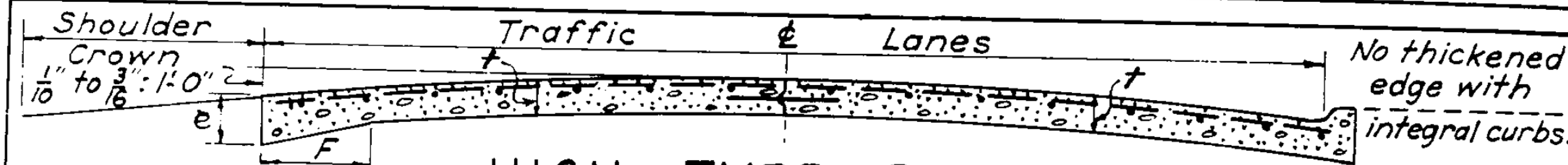
References: Highway Design & Construction by A.G. Bruce.
American Highway Practice, Vol. I & II by L.I. Hewes.

ROADS - TYPICAL SECTIONS - 2



HIGH TYPE - BITUMINOUS

CLASS OF ROAD	WEARING COURSE	BINDER COURSE	BASE COURSE
"AA", "A" or "B" "P", "T" or "M" Traffic	$1\frac{1}{2}$" bitum. concrete	$1\frac{1}{2}$" bitum. concrete	9" to 12" crushed stone
City Streets "P", "T" or "M" Traffic	$1\frac{1}{2}$" sheet asphalt	$1\frac{1}{2}$" asphaltic conc.	6" to 9" Portland cem. (may be old pavement)
"AA", "A" or "B" "P", "T" or "M" Traffic	2" bitum. concrete	Omitted	6" to 8" Portland cem.
"A", "B" or "C" "P" or "M" Traffic	2" bitum. concrete	3" bitum. Concrete	12" Gravel



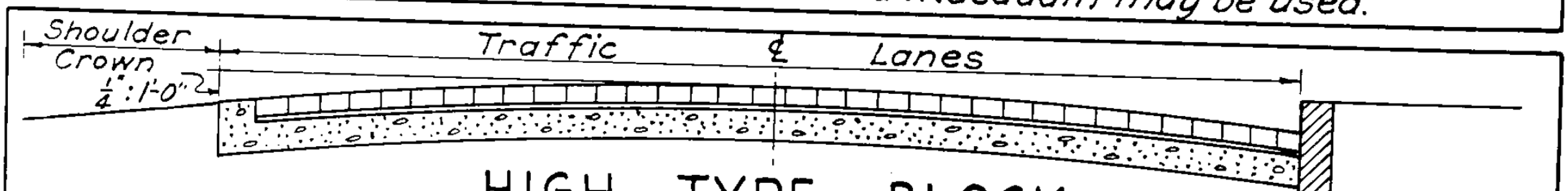
HIGH TYPE - RIGID

(PORTLAND CEMENT CONCRETE - PLAIN OR REINFORCED)

CLASS OF ROAD	t	e	F	TYPICAL DETAILS.
"AA", "A" or "B" "T" or "M" Traffic	7"	10"	2'-6"	Key center joint with $\frac{1}{2}$"ϕ x 2'-6" tie bars on 2'-6" centers. Dummy groove transverse joints spaced 15' to 25' with $\frac{3}{4}$"ϕ x 16" dowels on 12" centers. Transverse expansion joints spaced 60' to 120' with $\frac{3}{4}$"ϕ x 16" dowels on 12" ctrs. Typical mats are:- $\frac{3}{8}$"ϕ steel on 12" to 24" centers; #6 wire mesh on 6" x 6" centers; #3 wire mesh on 6" x 12" centers.
	8"	8"		
"B" or "C" "T" or "M" Traffic	6"	9"	2'-0"	
	7"	7"		
"C" or "D" "P" or "M" Traffic	$5\frac{1}{2}$"	8"	2'-0"	
	6"	6"		

Based on average sub-grades with concrete of 700# P.S.I. flexural strength.

NOTE:- Equivalent sections of cement bound macadam may be used.

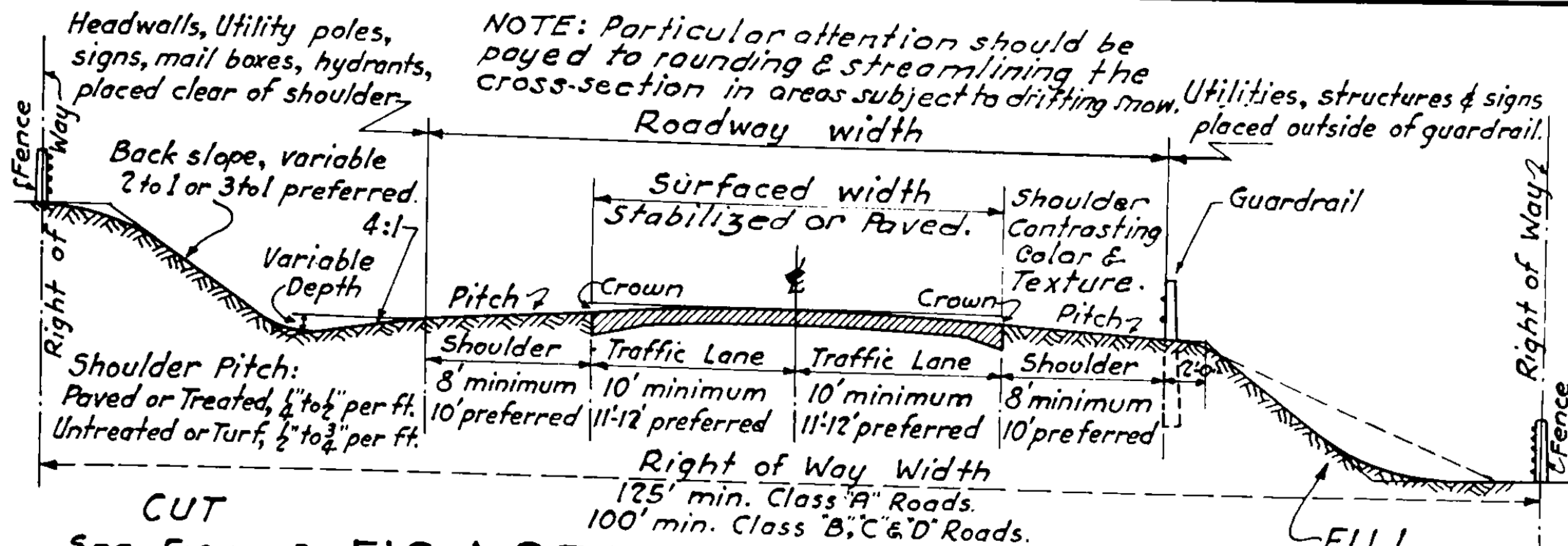


HIGH TYPE - BLOCK

MATERIAL	SIZE	FILLER	CUSHION	BASE	USAGE
Brick	3" x 4" x $8\frac{1}{2}$"	Bituminous	$\frac{3}{4}$" bitum. mastic	6" to 9" Concrete	City streets. Roads where economical.
Granite or stone	4" x 5" x 9"	Bituminous or grout	1" sand	6" to 9" Concrete	Heavy duty streets-dock & warehouse districts.
Asphalt	2" x 5" x 12"	Emulsified asphalt	$\frac{1}{2}$" mortar	6" reinf. Concrete	Bridge floors and approaches City streets.
Wood (creosoted)	3" x 4" x 8"	Bituminous or sand	$\frac{1}{2}$" bitum.	6" reinf. Concrete	Bridge floors. City streets.

Ref.: Asphalt Institute, Portland Cement Association (P.C.A.), Hard Pavements by A.G. Bruce.

ROADS - DESIGN OF CROSS - SECTION



CUT
SEE FIGURE B. **FIG. A-CROSS - SECTION** FILL SEE FIGURE C.

SCALE: 1" = 10'-0"

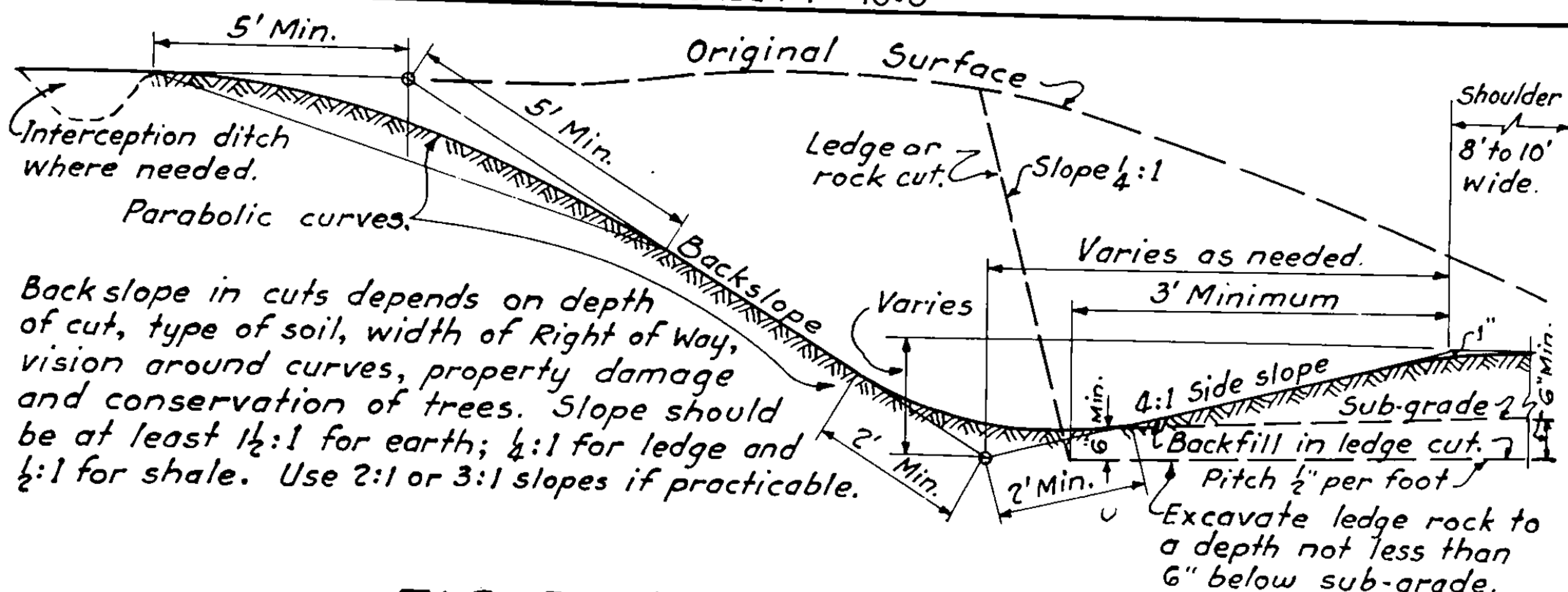


FIG. B- SLOPES IN CUTS

SCALE: ⅜" = 1'-0"

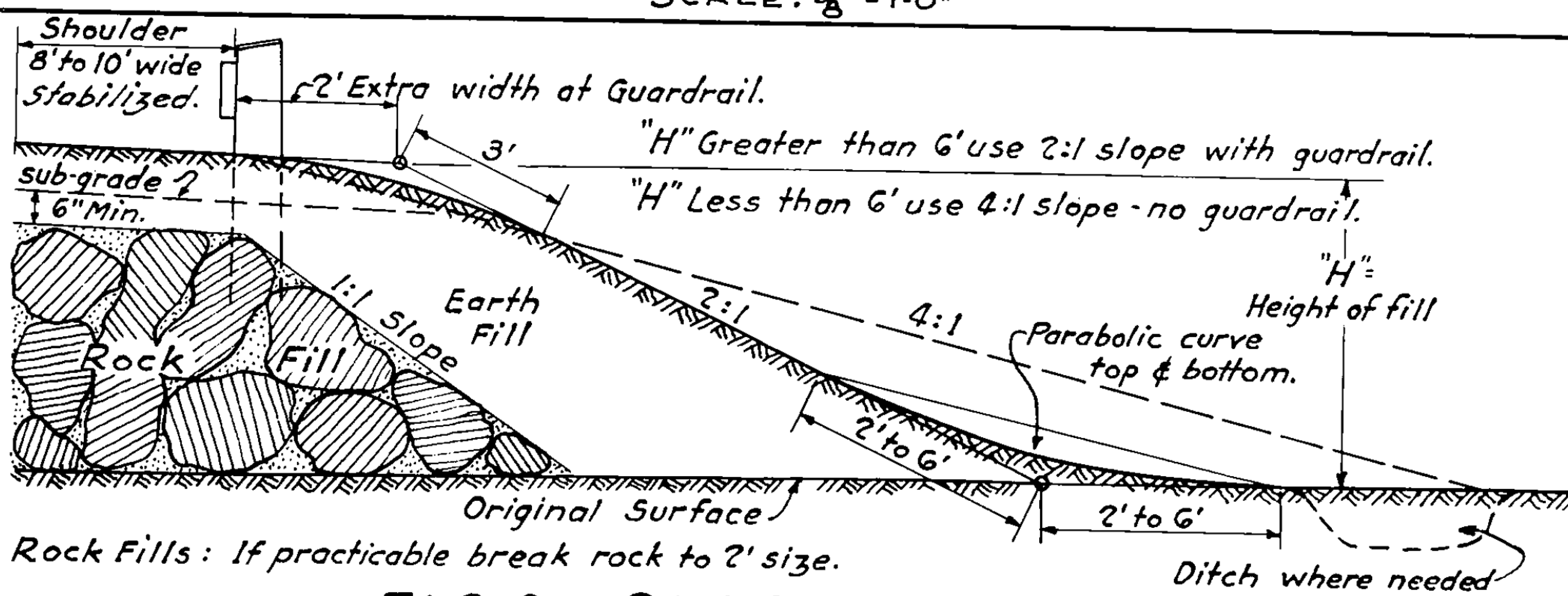


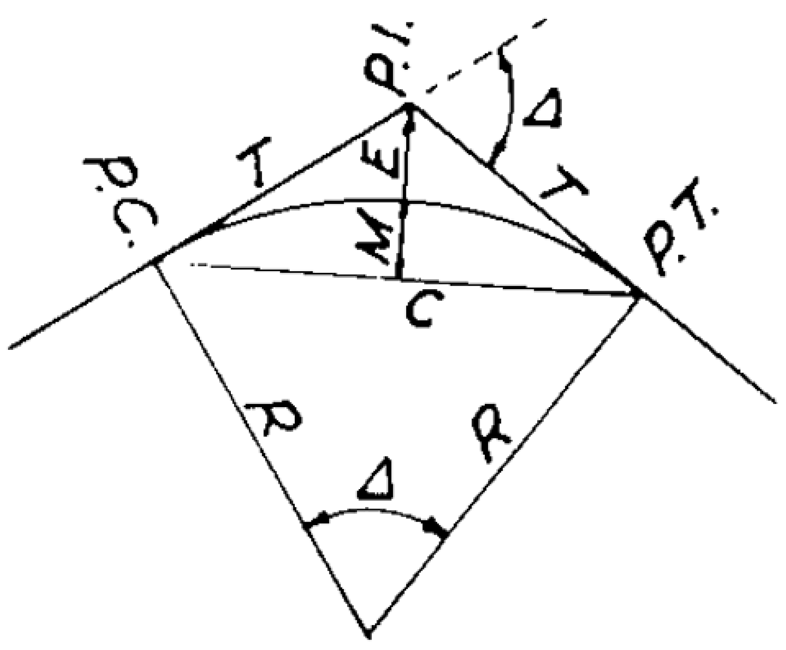
FIG.C -SLOPES IN FILLS

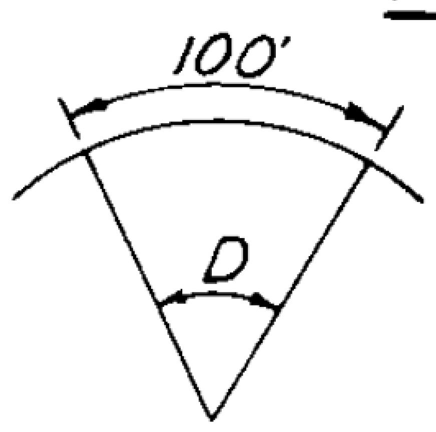
SCALE: ⅜" = 1'-0"

Ref.: Highway Design Policies by A. A. S. H. O.

ROADS - CIRCULAR CURVES - 1

ARC DEFINITION.





D (in degrees) subtends 100' of arc.

Formulas

$R = \frac{5729.58}{D}$

$T = R \tan \frac{\Delta}{2}$; $T = \frac{\tan 1° \text{ curve for } \Delta}{D}$

$L = \text{Length} = \frac{100\Delta}{D}$

$M = R(1 - \cos \frac{1}{2}\Delta)$

$E = R\left(\frac{1}{\cos\frac{1}{2}\Delta} - 1\right)$; $E = \frac{\text{ext. } 1° \text{ curve for } \Delta}{D}$

$C = 2R \sin \frac{\Delta}{2}$

$D = \frac{5729.58}{R}$

Example

Given:

$\Delta = 54°20'$; $D = 7°40'$; P.I. = Sta. 125 + 39.88

Required:

R; T; L and Sta. of P.C. and P.T.

Solution:

$R = \frac{5729.58}{7°40'} = 747.34'$

$T = 747.34(\tan 27°10') = 747.34(0.513195) = 383.53'$

Also- From Pg. 3-48 (Funct. 1° Curve) by interpolation tan 1° curve for Δ 54°20' = 2940.41

$\therefore T = \frac{2940.41}{7°40'} = 383.53'$

P.C. = Sta. 125 + 39.88 − 383.53 = Sta. 121 + 56.35

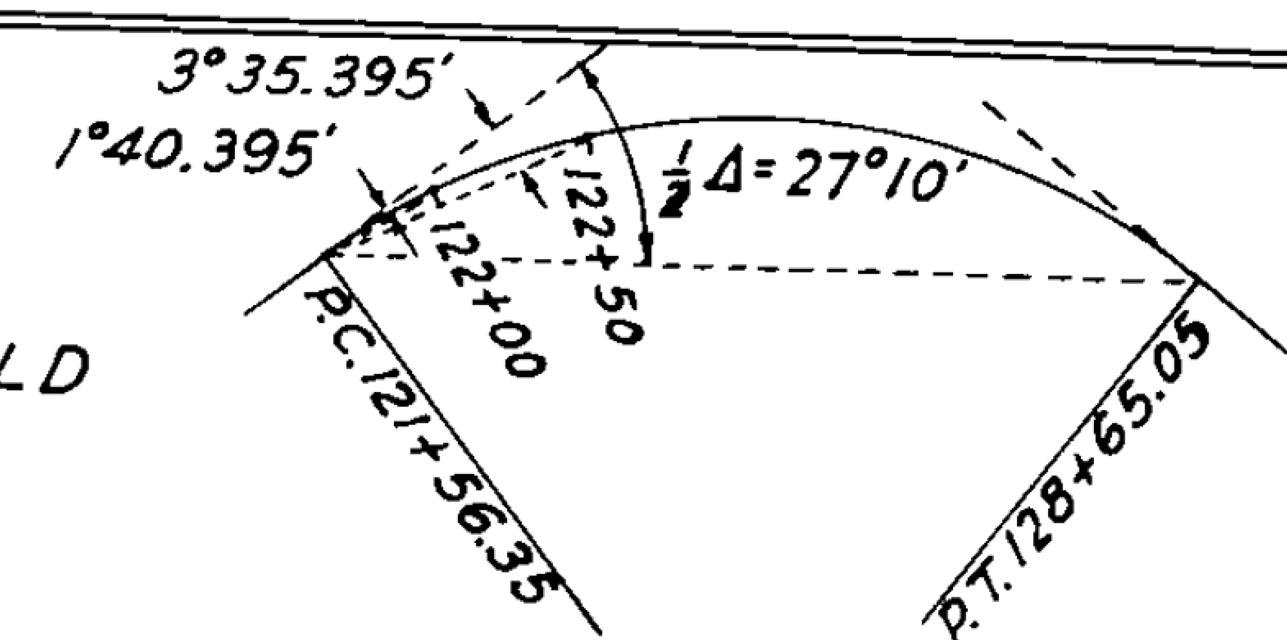
$L = \frac{100\Delta}{D} = \frac{100(54°20')}{7°40'} = 708.70'$

P.T. = Sta. 121 + 56.35 + 708.70 = Sta. 128 + 65.05

DEFINITIONS

L = Length of circular curve
P.I. = Point of intersection
P.C. = Point of curvature
P.T. = Point of tangency

DEFLECTIONS



Formulas

Deflection angle = $\frac{D}{2}$ for 100'; $\frac{D}{4}$ for 50', etc.

For "c" feet (in minutes) = 0.3 c D

Deflection angle (in minutes) from P.C. to P.T. = 0.3 L D

Also- Deflection angle (in degrees) from P.C. to P.T. = $\frac{\Delta}{2}$

Example

Given:

$\Delta = 54°20'$; $D = 7°40'$; L = 708.70; P.C. = Sta. 121 + 56.35; P.T. = Sta. 128 + 65.05

Required:

Deflection angle from P.C. to Sta. 122+00; Sta. 122+50 and P.T. Sta. 128 + 65.05

Solution:

Sta. 122+00 − P.C. Sta. 121 + 56.35 = 43.65'

$\therefore$ Deflection angle to Sta. 122+00 = $0.3 \times 43.65 \times 7°40' = 100.395' = 1°40.395'$

Deflection angle to Sta. 122+50 = $1°40.395' + \frac{7°40'}{4} = 1°40.395' + 1°55' = 3°35.395'$

Deflection angle to P.T. Sta. 128 + 65.05 = $0.3 \times 708.70 \times 7°40' = 27°10'$

Also- Deflection angle to P.T. Sta. 128 + 65.05 = $\frac{\Delta}{2} = \frac{54°20'}{2} = 27°10'$

EXTERNALS

Example

Given:

$\Delta = 54°20'$; $D = 7°40'$; $R = 747.34'$

Required:

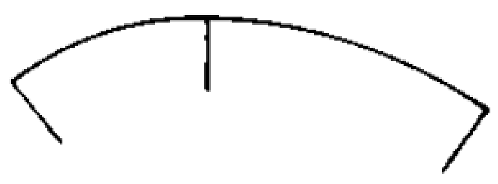
External "E"

Solution:

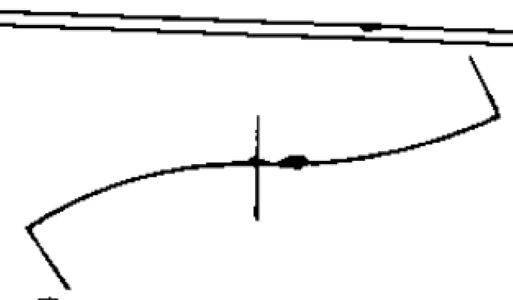
$E = 747.34\left(\frac{1}{.8896822} - 1\right) = 92.67'$

Also- From Pg. 3-48 (Funct. 1° curve) by interpolation external 1° curve for Δ 54°20' = 710.48

$\therefore E = \frac{710.48}{7°40'} = 92.67'$



Compound curve
Avoid



Reverse curve
Avoid

Broken-back curve
Avoid

MINIMUM CURVATURE *

The curve should be at least 500 feet long for Δ=5 degrees and increase 100 feet in length for each decrease of 1 degree in the Δ.

Where topography permits, use simple 0°20' to 1°00' curves without superelevation or widening.

MAXIMUM CURVATURE *

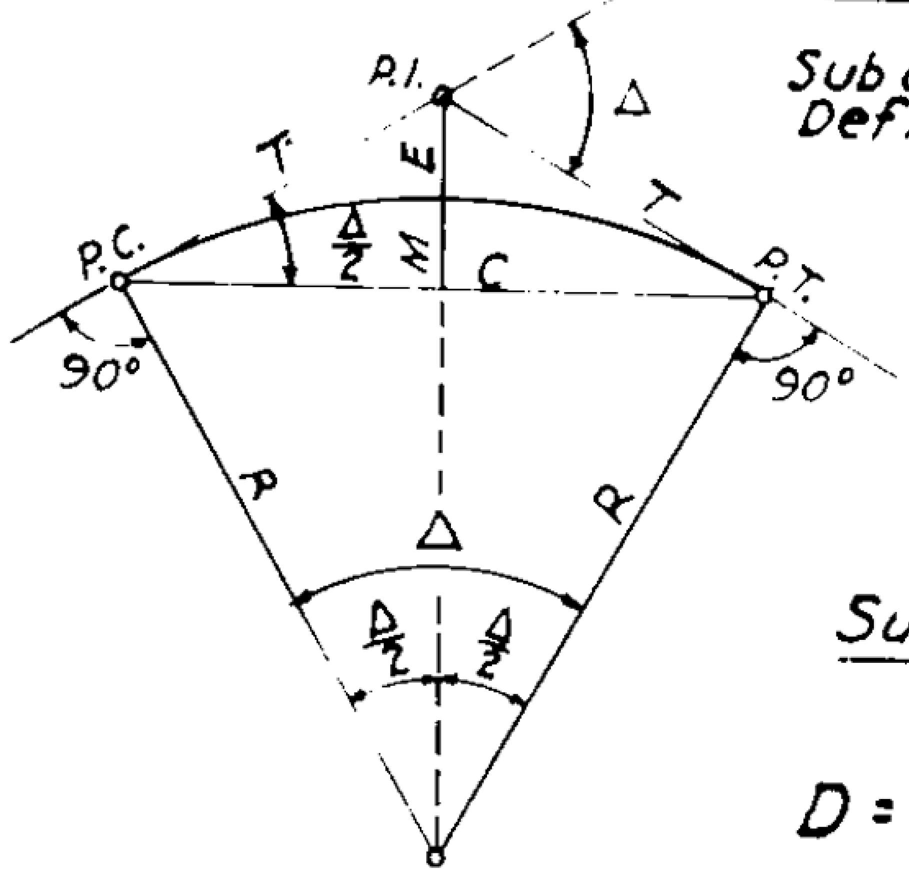
ASSUMED DESIGN SPEED M.P.H.	DEGREE OF CURVE DESIRABLE MAXIMUM	ABSOLUTE MAXIMUM
30	20	25
40	11	14
50	7	9
60	5	6
70	3	4

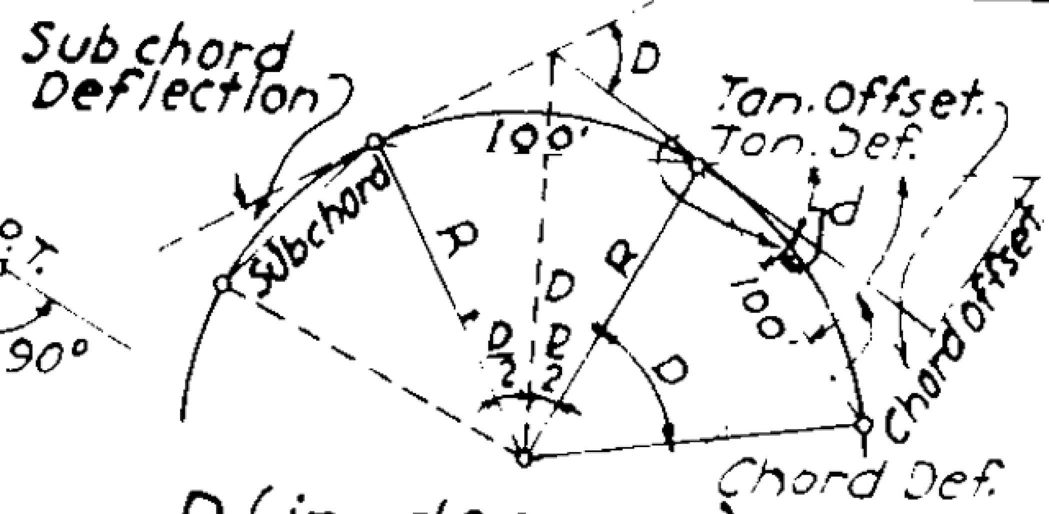
TANGENT OFFSETS: The approximate offset from the tangent to the curve at any distance from the P.C. $= \frac{\text{distance}^2}{2R}$

* From Geometric Design Standards by A.A.S.H.O.

ROADS — CIRCULAR CURVES-2

CHORD DEFINITION (R. R. CURVE).





D (in degrees) Subtends 100' Chord.

$$D = 100\,\Delta/L$$

$$D = \frac{\text{Tan. } 1^\circ \text{ curve}}{T} \text{ (approx).}$$

$$D = \frac{\text{Ext. } 1^\circ \text{ curve}}{E} \text{ (approx).}$$

Tan Offset $= \frac{Chord^2}{2R}$ = Chord · sin def.

$= \left(\frac{Chord^2}{100}\right)$ Tan Offset Table A.

Chord Offset = 2 Tan Defl. for 100' Chord = 100 sin D°

Tan Def = $\frac{1}{2}$ D $\frac{Chord}{100}$; For "c" feet = 0.3D×c = Def. for 1' in Table A × c.

Chord Def. = 2 Tan Def. = D for 100' Chord.

FORMULAS:

$R = \frac{50}{\sin D/2}$; $R = T \cdot \cot an \frac{\Delta}{2}$; $R = \frac{E}{\operatorname{exsec} \Delta/2}$

$T = R \cdot \tan \frac{\Delta}{2}$; $T = \frac{50 \tan \Delta/2}{\sin \Delta/2}$; $T = \frac{\tan 1^\circ \text{curve}}{D} + \text{Corr.}^{+}$

$L = 100 \frac{\Delta}{D}$; $\Delta = \frac{DL}{100}$; $M = R(1 - \cos \frac{\Delta}{2})$; $M = R \operatorname{vers} \frac{\Delta}{2}$

$E = T \cdot \tan \frac{\Delta}{4}$; $E = \frac{R}{\cos \Delta/2} - R$; $E = R \cdot \operatorname{exsec} \frac{\Delta}{2}$.

$C = 2R \cdot \sin \frac{\Delta}{2}$; $E = \frac{\text{ext. } 1^\circ \text{Curve}}{D} + \text{Correction}^{+}$

$\sin D/2 = \frac{50}{R}$; $\sin D/2 = \frac{50 \tan \Delta/2}{T}$

Example: Given: Δ = 54° 20'; D = 7°40'
P.I. Sta. 125+39.88.
Required: R, T, L, P.C. & P.T.
Solution: R = 50 ÷ Sin 3°50' = 747.89.
T = 747.89 (tan 27°10') = 383.81.
L = 100 Δ ÷ D = 100 (54° 20') ÷ 7°40' = 708.70.
P.C. = P.I. Sta. 125+39.88 − 383.81 = Sta. 121+56.07
P.T. = Sta. 121+56.07 + 708.70 = Sta. 128+64.77.

+ See page 3-49.

TABLE A - RADII, DEFLECTIONS, OFFSETS, ORDINATES, CHORDS & ARCS - 100' CHORD.*

D	RADIUS	DEF. FOR 1 FOOT	TAN OFF-SET.	MID ORD.	FOR SUB-CHORDS ADD 10'	20'	25'	50'	ACTUAL ARC PER 100' STA.	LONG CHORDS 2 STA.	3 STA.	4 STA.	5 STA.	D
30'	11,459.2	0.15	0.436	0.109					100.000	200.000	299.99	399.98	499.96	30'
1°	5,729.65	0.30	0.873	0.218					100.001	199.99	299.97	399.92	499.85	1°
30'	3,819.83	0.45	1.309	0.327					100.003	199.98	299.93	399.83	499.66	30'
2°	2,864.93	0.60	1.745	0.436					100.005	199.97	299.88	399.70	499.39	2°
30'	2,292.01	0.75	2.181	0.545					100.008	199.95	299.81	399.52	499.05	30'
3°	1,910.08	0.90	2.618	0.654					100.011	199.93	299.73	399.32	498.63	3°
30'	1,637.28	1.05	3.054	0.764					100.015	199.91	299.63	399.07	498.14	30'
4°	1,432.69	1.20	3.490	0.872				0.01	100.020	199.88	299.51	398.78	497.57	4°
30'	1,273.57	1.35	3.926	0.982				0.01	100.026	199.85	299.38	398.46	496.92	30'
5°	1,146.28	1.50	4.362	1.091			0.01	0.01	100.032	199.81	299.24	398.10	496.20	5°
30'	1,042.14	1.65	4.798	1.200			0.01	0.01	100.038	199.77	299.08	397.70	495.41	30'
6°	955.37	1.80	5.234	1.309		0.01	0.01	0.02	100.046	199.73	298.90	397.26	494.53	6°
30'	881.95	1.95	5.669	1.418		0.01	0.01	0.02	100.054	199.68	298.71	396.79	493.59	30'
7°	819.02	2.10	6.105	1.528		0.01	0.01	0.02	100.062	199.63	298.51	396.28	492.57	7°
8°	716.78	2.40	6.976	1.746	0.01	0.02	0.02	0.03	100.081	199.51	298.05	395.14	490.31	8°
10°	573.69	3.00	8.716	2.183	0.01	0.02	0.03	0.05	100.127	199.24	296.96	392.42	484.90	10°
12°	478.34	3.60	10.45	2.620	0.02	0.04	0.04	0.07	100.183	198.90	295.63	389.12	478.34	12°
14°	410.28	4.20	12.18	3.058	0.02	0.05	0.06	0.09	100.249	198.51	294.06	385.23	470.65	14°
16°	359.27	4.80	13.92	3.496	0.03	0.06	0.08	0.12	100.326	198.05	292.25	380.76	461.86	16°
18°	319.62	5.40	15.64	3.935	0.04	0.08	0.10	0.15	100.412	197.54	290.21	375.74	452.02	18°
20°	287.94	6.00	17.37	4.374	0.05	0.10	0.12	0.19	100.510	196.96	287.94	370.17	441.15	20°
22°	262.04	6.60	19.08	4.814	0.06	0.12	0.14	0.23	100.617	196.33	285.44	364.06	429.31	22°
24°	240.49	7.20	20.79	5.255	0.07	0.14	0.17	0.28	100.735	195.63	282.71	357.43	416.54	24°
30°	193.18	9.00	25.88	6.583	0.11	0.22	0.29	0.43	101.152	193.19	273.21	334.61	373.21	30°

USE OF TABLES A & B

GIVEN	REQUIRED.	SOLUTION.
D = 2°30'	Deflection for 35 ft.	= 0.75 × 35 = 26.25 = 26' 15"
D = 4°	Tan Offset for 125 ft.	= 3.49 $(\frac{125}{100})^2$ = 5.45 ft.
D = 10°	Mid Ord. for 30 ft. chord	= 0.0001 × 30² × 2.183 = 0.196 ft.
D = 14°	Length of nominal 20 ft. sub chord.	= 20 + 0.05 = 20.05 ft.
D = 20°	Actual length of arc for L = 600 ft. (6 Sta.)	= 100.51 × 6 = 603.06 ft.
D = 3°	Long chord for 3 Sta.	= From Table A = 299.73 ft.
Δ = 27°05'11"	Δ in decimals of °	From Table B = 27 + 0.0833 + 11 × 0.000278 = 27.086°

TABLE B - MINUTES IN DECIMALS OF A DEGREE. SECONDS IN DECIMALS OF A MINUTE. *

1	0.0167	11	0.1833	21	0.3500	31	0.5167	41	0.6833	51	0.8500
2	0.0333	12	0.2000	22	0.3667	32	0.5333	42	0.7000	52	0.8667
3	0.0500	13	0.2167	23	0.3833	33	0.5500	43	0.7167	53	0.8833
4	0.0667	14	0.2333	24	0.4000	34	0.5667	44	0.7333	54	0.9000
5	0.0833	15	0.2500	25	0.4167	35	0.5833	45	0.7500	55	0.9167
6	0.1000	16	0.2667	26	0.4333	36	0.6000	46	0.7667	56	0.9333
7	0.1167	17	0.2833	27	0.4500	37	0.6167	47	0.7833	57	0.9500
8	0.1333	18	0.3000	28	0.4667	38	0.6333	48	0.8000	58	0.9667
9	0.1500	19	0.3167	29	0.4833	39	0.6500	49	0.8167	59	0.9833
10	0.1667	20	0.3333	30	0.5000	40	0.6667	50	0.8333	60	1.0000

Proportional Part for 1" = 0.000278 of 1°

*Adapted from Railroad Curve Tables by Eugene Dietzgen Co., Ref. Field Engineering by Searles & Ives

ROADS — FUNCTIONS OF 1° CURVE

See Pg. 3-46 for use of table.

CENTRAL ANGLE	TANGENT	EXTERNAL	CENTRAL ANGLE	TANGENT	EXTERNAL	CENTRAL ANGLE	TANGENT	EXTERNAL	CENTRAL ANGLE	TANGENT	EXTERNAL
1°	50.00	0.22	31°	1588.95	216.25	61°	3374.98	920.1	91°	5830.46	2444.9
30'	75.00	0.49	30'	1615.91	223.51	30'	3408.74	937.3	30'	5881.58	2481.5
2°	100.01	0.87	32°	1642.93	230.90	62°	3442.68	954.8	92°	5933.15	2518.5
30'	125.02	1.36	30'	1670.02	238.43	30'	3476.79	972.4	30'	5985.20	2556.0
3°	150.03	1.96	33°	1697.18	246.08	63°	3511.09	990.2	93°	6037.72	2594.0
30'	175.05	2.67	30'	1724.41	253.87	30'	3545.57	1008.3	30'	6090.72	2632.6
4°	200.08	3.49	34°	1751.71	261.80	64°	3580.24	1026.6	94°	6144.22	2671.6
30'	225.12	4.42	30'	1779.08	269.86	30'	3615.09	1045.2	30'	6198.22	2711.2
5°	250.16	5.46	35°	1806.53	278.05	65°	3650.14	1063.9	95°	6252.74	2751.3
30'	275.21	6.61	30'	1834.05	286.39	30'	3685.39	1082.9	30'	6307.77	2792.0
6°	300.27	7.86	36°	1861.65	294.86	66°	3720.83	1102.2	96°	6363.34	2833.2
30'	325.35	9.23	30'	1889.33	303.47	30'	3756.48	1121.7	30'	6419.45	2875.0
7°	350.44	10.71	37°	1917.09	312.22	67°	3792.33	1141.4	97°	6476.11	2917.3
30'	375.54	12.29	30'	1944.93	321.11	30'	3828.38	1161.3	30'	6533.33	2960.3
8°	400.65	13.99	38°	1972.85	330.15	68°	3864.65	1181.6	98°	6591.13	3003.8
30'	425.78	15.80	30'	2000.86	339.32	30'	3901.13	1202.0	30'	6649.50	3047.9
9°	450.93	17.72	39°	2028.95	348.64	69°	3937.83	1222.7	99°	6708.47	3092.7
30'	476.09	19.75	30'	2057.13	358.11	30'	3974.75	1243.7	30'	6768.05	3138.1
10°	501.27	21.89	40°	2085.40	367.72	70°	4011.89	1265.0	100°	6828.25	3184.1
30'	526.47	24.14	30'	2113.75	377.47	30'	4049.27	1286.5	30'	6889.07	3230.8
11°	551.70	26.50	41°	2142.20	387.38	71°	4086.87	1308.2	101°	6950.53	3278.1
30'	576.94	28.97	30'	2170.74	397.43	30'	4124.71	1330.3	30'	7012.65	3326.1
12°	602.20	31.56	42°	2199.38	407.64	72°	4162.78	1352.6	102°	7075.44	3374.9
30'	627.49	34.26	30'	2228.11	417.99	30'	4201.10	1375.2	30'	7138.91	3424.3
13°	652.80	37.07	43°	2256.94	428.50	73°	4239.66	1398.0	103°	7203.07	3474.4
30'	678.14	39.99	30'	2285.87	439.16	30'	4278.48	1421.2	30'	7267.94	3525.2
14°	703.50	43.03	44°	2314.90	449.98	74°	4317.55	1444.6	104°	7333.53	3576.8
30'	728.89	46.18	30'	2344.03	460.95	30'	4356.87	1468.4	30'	7399.85	3629.2
15°	754.31	49.44	45°	2373.27	472.08	75°	4396.46	1492.4	105°	7466.93	3682.3
30'	779.76	52.82	30'	2402.61	483.37	30'	4436.31	1516.7	30'	7534.78	3736.2
16°	805.24	56.31	46°	2432.06	494.82	76°	4476.44	1541.4	106°	7603.41	3791.0
30'	830.75	59.91	30'	2461.62	506.42	30'	4516.83	1566.3	30'	7672.84	3846.5
17°	856.29	63.63	47°	2491.29	518.20	77°	4557.51	1591.6	107°	7743.08	3902.9
30'	881.87	67.47	30'	2521.07	530.13	30'	4598.47	1617.1	30'	7814.16	3960.1
18°	907.48	71.42	48°	2550.97	542.23	78°	4639.72	1643.0	108°	7886.09	4018.2
30'	933.12	75.49	30'	2580.99	554.50	30'	4681.26	1669.2	30'	7958.89	4077.2
19°	958.80	79.67	49°	2611.12	566.94	79°	4723.10	1695.8	109°	8032.57	4137.1
30'	984.52	83.97	30'	2641.37	579.54	30'	4765.24	1722.7	30'	8107.17	4197.9
20°	1010.28	88.39	50°	2671.75	592.32	80°	4807.69	1749.9	110°	8182.69	4259.7
30'	1036.08	92.92	30'	2702.24	605.27	30'	4850.45	1777.4	30'	8259.15	4322.4
21°	1061.91	97.58	51°	2732.87	618.39	81°	4893.52	1805.3	111°	8336.59	4386.1
30'	1087.79	102.35	30'	2763.62	631.69	30'	4936.92	1833.6	30'	8415.01	4450.9
22°	1113.72	107.24	52°	2794.50	645.17	82°	4980.65	1862.2	112°	8494.45	4516.6
30'	1139.68	112.25	30'	2825.52	658.83	30'	5024.71	1891.2	30'	8574.92	4583.4
23°	1165.70	117.38	53°	2856.66	672.66	83°	5069.10	1920.5	113°	8656.45	4651.3
30'	1191.75	122.63	30'	2887.95	686.68	30'	5113.84	1950.3	30'	8739.06	4720.3
24°	1217.86	128.00	54°	2919.37	700.89	84°	5158.93	1980.4	114°	8822.78	4790.4
30'	1244.01	133.50	30'	2950.93	715.28	30'	5204.38	2010.8	30'	8907.63	4861.7
25°	1270.22	139.11	55°	2982.63	729.85	85°	5250.19	2041.7	115°	8993.64	4934.1
30'	1296.47	144.85	30'	3014.48	744.62	30'	5296.37	2073.0	30'	9080.83	5007.8
26°	1322.78	150.71	56°	3046.47	759.58	86°	5342.92	2104.7	116°	9169.24	5082.7
30'	1349.14	156.70	30'	3078.61	774.73	30'	5389.85	2136.7	30'	9258.89	5158.8
27°	1375.55	162.81	57°	3110.91	790.08	87°	5437.17	2169.2	117°	9349.82	5236.2
30'	1402.02	169.04	30'	3143.35	805.62	30'	5484.88	2202.2	30'	9442.05	5315.0
28°	1428.54	175.41	58°	3175.96	821.37	88°	5532.99	2235.5	118°	9535.62	5395.1
30'	1455.13	181.89	30'	3208.72	837.31	30'	5581.51	2269.3	30'	9630.55	5476.5
29°	1481.77	188.51	59°	3241.64	853.46	89°	5630.44	2303.5	119°	9726.89	5559.4
30'	1508.47	195.25	30'	3274.72	869.82	30'	5679.79	2338.2	30'	9824.67	5643.8
30°	1535.24	202.12	60°	3307.97	886.38	90°	5729.58	2373.3	120°	9923.92	5729.7
30'	1562.06	209.12	30'	3341.39	903.15	30'	5779.80	2408.9	30'	10024.68	5817.0

ROADS-CORRECTIONS FOR TANGENTS & EXTERNALS

For railroad and highway curves laid out by the chord definition these corrections are to be added to the values found, using tables on page 3-48 in order to obtain the corrected tangents and external distances.

For Tangents Add *

Central Angle	Degree of Curve 5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°
10°	.03	.06	.09	.13	.16	.19	.22	.25	.28	.31	.34	.38	.42	.46
15°	.04	.10	.14	.19	.24	.29	.34	.39	.45	.51	.53	.58	.63	.68
20°	.06	.13	.19	.26	.32	.39	.45	.51	.58	.65	.72	.79	.84	.90
25°	.08	.16	.24	.33	.40	.49	.58	.67	.75	.83	.90	.99	1.06	1.14
30°	.10	.19	.29	.39	.49	.59	.69	.79	.89	.99	1.09	1.20	1.29	1.39
35°	.11	.22	.34	.47	.58	.69	.70	.81	.92	1.04	1.29	1.42	1.54	1.66
40°	.13	.26	.40	.53	.67	.80	.93	1.06	1.20	1.34	1.49	1.64	1.79	1.94
45°	.15	.30	.44	.60	.76	.91	1.06	1.21	1.37	1.52	1.70	1.87	2.04	2.21
50°	.17	.34	.51	.68	.85	1.02	1.19	1.36	1.54	1.72	1.91	2.10	2.29	2.48
55°	.19	.38	.57	.76	.95	1.14	1.32	1.52	1.72	1.92	2.14	2.35	2.56	2.77
60°	.21	.42	.63	.84	1.05	1.27	1.49	1.71	1.94	2.17	2.38	2.60	2.83	3.07
65°	.23	.46	.69	.93	1.16	1.40	1.64	1.88	2.13	2.38	2.63	2.88	3.13	3.39
70°	.25	.51	.76	1.02	1.28	1.54	1.80	2.06	2.33	2.60	2.88	3.16	3.44	3.72
75°	.27	.56	.83	1.12	1.40	1.69	1.98	2.27	2.57	2.87	3.16	3.47	3.78	4.09
80°	.30	.61	.91	1.22	1.53	1.84	2.15	2.46	2.78	3.10	3.44	3.78	4.12	4.46
85°	.33	.66	1.00	1.33	1.68	2.02	2.36	2.70	3.05	3.40	3.77	4.14	4.55	4.89
90°	.36	.72	1.09	1.45	1.83	2.20	2.57	2.94	3.32	3.70	4.10	4.50	4.91	5.32
95°	.39	.79	1.19	1.55	2.00	2.40	2.80	3.20	3.61	4.02	4.40	4.98	5.38	6.83
100°	.43	.86	1.30	1.74	2.18	2.62	3.06	3.50	3.95	4.40	4.88	5.37	5.85	6.34
110°	.51	1.03	1.56	2.08	2.61	3.14	3.67	4.21	4.76	5.31	5.86	6.43	7.01	7.60
120°	.62	1.25	1.93	2.52	3.16	3.81	4.45	5.11	5.77	6.44	7.12	7.80	8.50	9.22

For Externals Add *

Central Angle.	Degree of Curve 5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°
10°	.001	.003	.004	.006	.007	.008	.009	.011	.012	.014	.015	.017	.018	.020
15°	.003	.007	.010	.014	.018	.023	.027	.029	.032	.035	.039	.043	.047	.051
20°	.006	.011	.017	.022	.028	.034	.038	.045	.051	.057	.063	.070	.076	.083
25°	.009	.018	.027	.036	.046	.056	.065	.074	.083	.093	.106	.120	.127	.135
30°	.013	.025	.038	.051	.065	.078	.090	.103	.116	.129	.149	.170	.179	.188
35°	.018	.035	.054	.072	.086	.109	.131	.153	.175	.197	.213	.230	.247	.264
40°	.023	.046	.070	.093	.117	.141	.172	.203	.234	.265	.277	.290	.315	.341
45°	.030	.060	.093	.119	.153	.184	.216	.254	.289	.325	.351	.378	.411	.445
50°	.037	.075	.116	.151	.189	.227	.266	.305	.345	.384	.425	.467	.508	.550
55°	.046	.093	.142	.188	.236	.283	.332	.381	.420	.479	.530	.582	.641	.700
60°	.056	.112	.168	.225	.283	.340	.398	.457	.516	.575	.636	.697	.774	.851
65°	.067	.135	.204	.273	.343	.412	.483	.554	.625	.697	.711	.845	.922	1.01
70°	.080	.159	.240	.321	.403	.485	.568	.652	.735	.819	.906	.994	1.08	1.17
75°	.095	.182	.286	.383	.480	.578	.678	.777	.877	.977	1.07	1.18	1.29	1.39
80°	.110	.220	.332	.445	.558	.671	.787	.903	1.02	1.13	1.25	1.38	1.50	1.62
85°	.128	.259	.391	.524	.057	.790	.926	1.06	1.20	1.34	1.47	1.62	1.76	1.91
90°	.149	.299	.450	.603	.756	.910	1.07	1.22	1.38	1.54	1.70	1.87	2.03	2.20
95°	.174	.350	.522	.706	.985	1.06	1.25	1.43	1.62	1.80	1.99	2.18	2.38	2.58
100°	.200	.401	.604	.809	1.01	1.22	1.43	1.64	1.85	2.06	2.28	2.50	2.73	2.96
110°	.268	.536	.806	1.08	1.35	1.63	1.91	2.20	2.48	2.76	3.05	3.35	3.66	3.96
120°	.360	.721	1.08	1.45	1.82	2.19	2.57	2.95	3.33	3.72	4.11	4.50	4.91	5.32

* Adapted from: Dietzgen's Railroad Curve Tables by Eugene Dietzgen Co.

ROADS-DEFLECTIONS & CHORD LENGTHS FOR CIRCULAR CURVES

FOR LAYING OUT ARC DEFINITION CURVES BY MEASURED CHORDS.

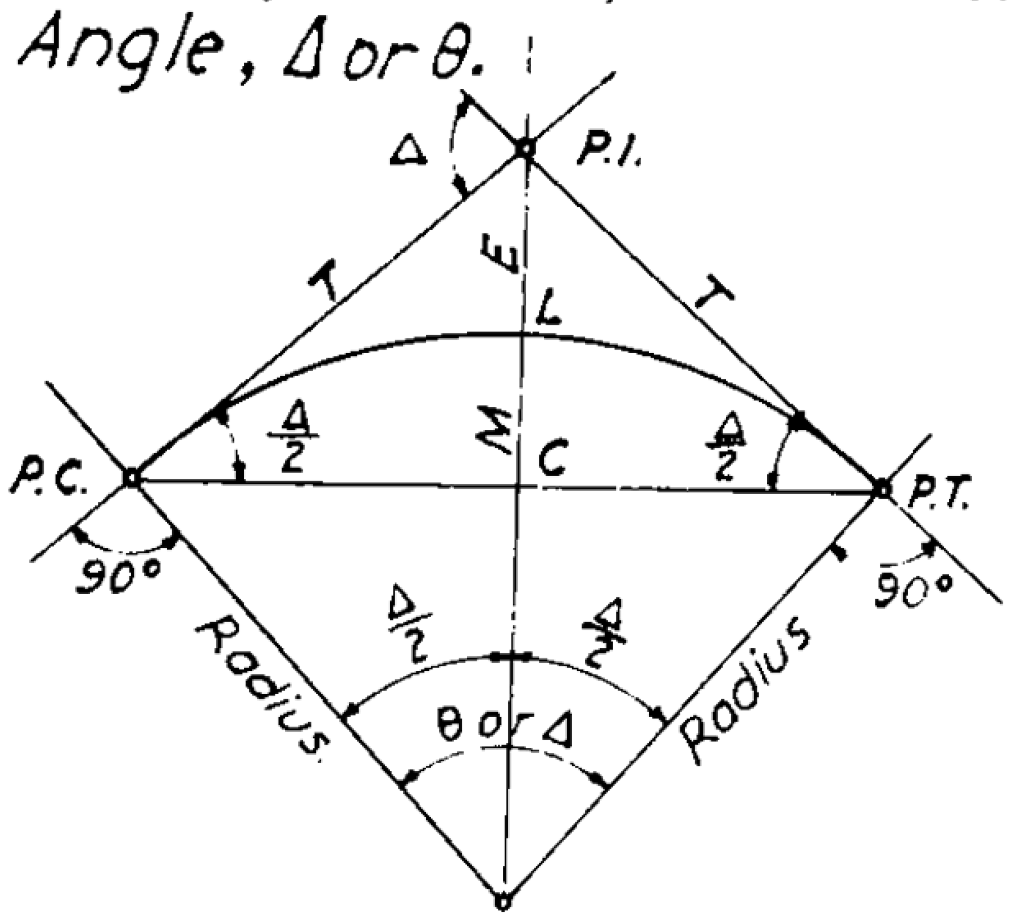
TABLE A - DEFLECTIONS AND CHORD LENGTHS.

DEGREE OF CURVE	RADIUS	DEFLECTION FOR ARC LENGTH: Deflection= Arc Length (0.3 Deg. of Curve)				CHORD FOR ARC LENGTH: Chord= 2 R sin Def.		
		1'	25'	50'	100'	25'	50'	100'
0°30'	11459.16	0° 00.15'	0° 03.75'	0° 07.50'	0° 15.00'	25.00'	50.00'	100.00'
1°	5729.58	0° 00.30'	0° 07.50'	0° 15.00'	0° 30.00'	25.00'	50.00'	100.00'
30'	3819.72	0° 00.45'	0° 11.25'	0° 22.50'	0° 45.00'	25.00'	50.00'	100.00'
2°	2864.79	0° 00.60'	0° 15.00'	0° 30.00'	1° 00.00'	25.00'	50.00'	100.00'
30'	2291.83	0° 00.75'	0° 18.75'	0° 37.50'	1° 15.00'	25.00'	50.00'	100.00'
3°	1909.86	0° 00.90'	0° 22.50'	0° 45.00'	1° 30.00'	25.00'	50.00'	99.99'
30'	1637.02	0° 01.05'	0° 26.25'	0° 52.50'	1° 45.00'	25.00'	50.00'	99.99'
4°	1432.40	0° 01.20'	0° 30.00'	1° 00.00'	2° 00.00'	25.00'	50.00'	99.98'
30'	1273.24	0° 01.35'	0° 33.75'	1° 07.50'	2° 15.00'	25.00'	50.00'	99.98'
5°	1145.92	0° 01.50'	0° 37.50'	1° 15.00'	2° 30.00'	25.00'	50.00'	99.97'
30'	1041.74	0° 01.65'	0° 41.25'	1° 22.50'	2° 45.00'	25.00'	50.00'	99.97'
6°	954.93	0° 01.80'	0° 45.00'	1° 30.00'	3° 00.00'	25.00'	50.00'	99.96'
30'	881.47	0° 01.95'	0° 48.75'	1° 37.50'	3° 15.00'	25.00'	50.00'	99.95'
7°	818.51	0° 02.10'	0° 52.50'	1° 45.00'	3° 30.00'	25.00'	50.00'	99.95'
30'	763.94	0° 02.25'	0° 56.25'	1° 52.50'	3° 45.00'	25.00'	49.99'	99.94'
8°	716.20	0° 02.40'	1° 00.00'	2° 00.00'	4° 00.00'	25.00'	49.99'	99.93'
30'	674.07	0° 02.55'	1° 03.75'	2° 07.50'	4° 15.00'	25.00'	49.99'	99.92'
9°	636.62	0° 02.70'	1° 07.50'	2° 15.00'	4° 30.00'	25.00'	49.99'	99.91'
30'	603.11	0° 02.85'	1° 11.25'	2° 22.50'	4° 45.00'	25.00'	49.99'	99.90'
10°	572.96	0° 03.00'	1° 15.00'	2° 30.00'	5° 00.00'	25.00'	49.98'	99.89'
11°	520.87	0° 03.30'	1° 22.50'	2° 45.00'	5° 30.00'	25.00'	49.98'	99.87'
12°	477.46	0° 03.60'	1° 30.00'	3° 00.00'	6° 00.00'	25.00'	49.98'	99.85'
13°	440.74	0° 03.90'	1° 37.50'	3° 15.00'	6° 30.00'	25.00'	49.97'	99.82'
14°	409.26	0° 04.20'	1° 45.00'	3° 30.00'	7° 00.00'	25.00'	49.97'	99.79'
15°	381.97	0° 04.50'	1° 52.50'	3° 45.00'	7° 30.00'	25.00'	49.96'	99.75'
16°	358.10	0° 04.80'	2° 00.00'	4° 00.00'	8° 00.00'	25.00'	49.96'	99.72'
17°	337.03	0° 05.10'	2° 07.50'	4° 15.00'	8° 30.00'	25.00'	49.95'	99.68'
18°	318.31	0° 05.40'	2° 15.00'	4° 30.00'	9° 00.00'	24.99'	49.95'	99.63'
19°	301.56	0° 05.70'	2° 22.50'	4° 45.00'	9° 30.00'	24.99'	49.94'	99.59'
20°	286.48	0° 06.00'	2° 30.00'	5° 00.00'	10° 00.00'	24.99'	49.94'	99.54'
21°	272.84	0° 06.30'	2° 37.50'	5° 15.00'	10° 30.00'	24.99'	49.93'	99.49'
22°	260.44	0° 06.60'	2° 45.00'	5° 30.00'	11° 00.00'	24.99'	49.92'	99.44'
23°	249.11	0° 06.90'	2° 52.50'	5° 45.00'	11° 30.00'	24.99'	49.92'	99.39'
24°	238.73	0° 07.20'	3° 00.00'	6° 00.00'	12° 00.00'	24.99'	49.91'	99.33'
								99.27'
38° 12'	150	0° 11.45'	4° 46.48'	9° 32.96'	19° 05.92'	24.97'	49.77'	98.16'
28° 39'	200	0° 08.59'	3° 34.86'	7° 09.72'	14° 19.44'	24.98'	49.87'	98.96'
25° 28'	225	0° 07.64'	3° 10.99'	6° 21.97'	12° 43.94'	24.99'	49.90'	99.18'
22° 55'	250	0° 06.88'	2° 51.89'	5° 43.78'	11° 27.55'	24.99'	49.92'	99.34'
20° 50'	275	0° 06.25'	2° 36.26'	5° 12.52'	10° 25.04'	24.99'	49.93'	99.45'
19° 06'	300	0° 05.73'	2° 23.24'	4° 46.48'	9° 32.96'	24.99'	49.94'	99.54'
17° 38'	325	0° 05.29'	2° 12.22'	4° 24.44'	8° 48.88'	24.99'	49.95'	99.61'
16° 22'	350	0° 04.91'	2° 02.78'	4° 05.55'	8° 11.11'	25.00'	49.96'	99.66'
15° 17'	375	0° 04.58'	1° 54.59'	3° 49.18'	7° 38.37'	25.00'	49.96'	99.70'
14° 19'	400	0° 04.30'	1° 47.43'	3° 34.86'	7° 09.72'	25.00'	49.97'	99.74'
12° 44'	450	0° 03.82'	1° 35.49'	3° 10.99'	6° 21.97'	25.00'	49.97'	99.79'
11° 28'	500	0° 03.44'	1° 25.94'	2° 51.89'	5° 43.77'	25.00'	49.98'	99.83'
10° 25'	550	0° 03.13'	1° 18.13'	2° 36.26'	5° 12.52'	25.00'	49.98'	99.86'
9° 33'	600	0° 02.86'	1° 11.62'	2° 23.24'	4° 46.48'	25.00'	49.99'	99.89'
8° 50'	650	0° 02.64'	1° 06.11'	2° 12.22'	4° 24.44'	25.00'	49.99'	99.90'
8° 11'	700	0° 02.46'	1° 01.39'	2° 02.78'	4° 05.55'	25.00'	49.99'	99.92'
7° 38'	750	0° 02.29'	0° 57.30'	1° 54.59'	3° 49.18'	25.00'	50.00'	99.93'
7° 10'	800	0° 02.15'	0° 53.71'	1° 47.43'	3° 34.86'	25.00'	50.00'	99.93'
6° 44'	850	0° 02.02'	0° 50.56'	1° 41.11'	3° 22.22'	25.00'	50.00'	99.94'
6° 22'	900	0° 01.91'	0° 47.75'	1° 35.49'	3° 10.99'	25.00'	50.00'	99.95'
6° 02'	950	0° 01.81'	0° 45.23'	1° 30.47'	3° 00.93'	25.00'	50.00'	99.95'
5° 44'	1000	0° 01.72'	0° 42.97'	1° 25.94'	2° 51.89'	25.00'	50.00'	99.96'

Deflection for curves of even radii = $\frac{1718.873}{R}$ Arc Length.

ROADS - SHORT RADIUS CURVES

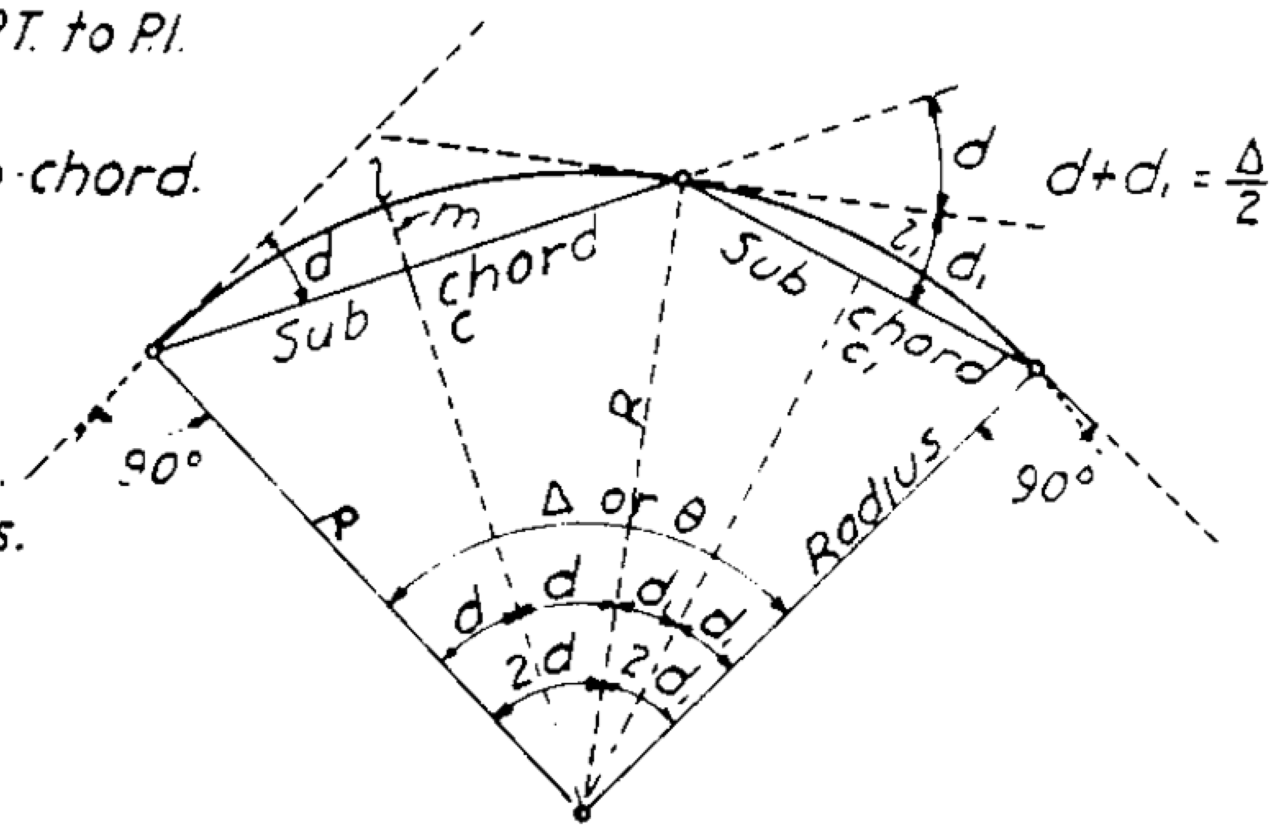
NOTE: The degree of curve is not usually used for the curves involved in street intersections, curbs, road intersections, runway and taxiway fillets, and turnarounds, traffic circles, rotaries, cloverleafs, etc. These curves are defined by the Radius, R, and Central Angle, Δ or θ.



SHORT RADIUS CURVE.

NOTATION:

- T = Tangent length · P.C. or P.T. to P.I.
- L = Arc length · P.C. to P.T.
- l = Arc length for any sub-chord.
- C = Long chord P.C. to P.T.
- c = Any sub-chord.
- d = Deflection to any point.
- Δ = Central Angle in degrees.
- θ = Central Angle in radians.
- One radian $= \frac{360°}{2\pi} = \frac{180°}{\pi}$ $= 57.2958°$ $= 57°17'44.8''$
- $\pi = 3.14159$
- M = Mid. Ordinate; m for sub-chords.
- E = External; e for sub-chords.



SUB-CHORDS AND DEFLECTIONS.

$R = \frac{L}{\theta} = \frac{L \cdot 180/\Delta}{\pi} = \frac{L}{\Delta}57.2958 = T\cdot \cot\frac{\Delta}{2} = \frac{C}{2\sin\Delta/2}$.

$= \frac{4M^2+C^2}{8M} = \frac{M^2+(C/2)^2}{2M}$.

$L = R\theta = \frac{\Delta R\pi}{180} = 0.017453\Delta R = \text{Circum.}\cdot\frac{\Delta}{360}$.

$T = R\cdot\tan\frac{\Delta}{2} = E\cdot\cot\frac{\Delta}{4} = \frac{C}{2\cos\Delta/2}$.

$C = 2R\cdot\sin\frac{\Delta}{2} = 2T\cdot\cos\frac{\Delta}{2} = 2\sqrt{M(2R-M)}$

$M = R\cdot\text{vers}\frac{\Delta}{2} = E\cdot\cos\frac{\Delta}{2} = R(1-\cos\frac{\Delta}{2})$.

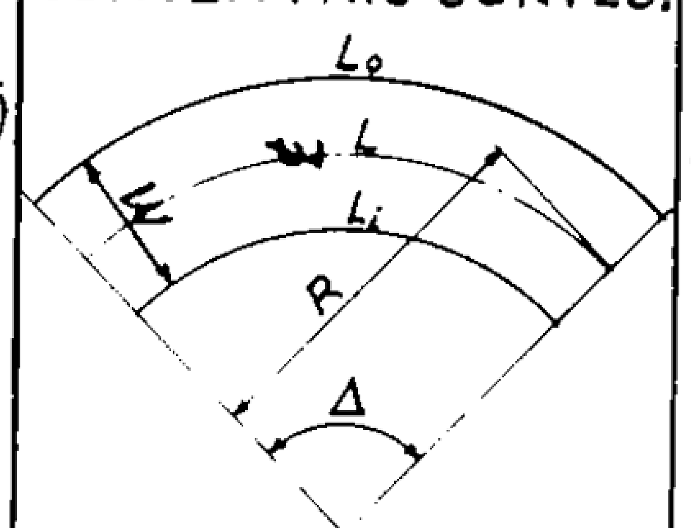
$E = R\cdot\text{exsec}\frac{\Delta}{2} = T\cdot\tan\frac{\Delta}{4} = \frac{R}{\cos\Delta/2} - R$.

$\Delta = \frac{180L}{\pi R} = 57.2958\frac{L}{R} = \theta\cdot 57.2958$.

$\theta = \frac{L}{R} = \frac{\Delta\pi}{180} = \Delta\cdot 0.017453$.

$\sin\frac{\Delta}{2} = \frac{C}{2R}$; $\cos\frac{\Delta}{2} = \frac{R-M}{R} = \frac{C}{2T}$; $\tan\frac{\Delta}{2} = \frac{T}{R}$

CONCENTRIC CURVES.



$L_o = \frac{R+W/2}{R}L$

$L_i = \frac{R-W/2}{R}L$

$L_o - L_i = 0.017453\,W\cdot\Delta$
$= W\cdot L/R$

Area $= L\cdot W$

Sub-chord $= 2R\cdot\sin d = 2(R-M)\cdot\tan d$.

d(in minutes) $= 1718.873\frac{l}{R}$. Radius $= \frac{c}{2\sin d}$.

length $= \frac{\pi R d}{90} = 0.034906\,R\,d$ (d in degrees).

mid-ordinate $= R(1-\cos d) = 2R\cdot\sin^2\frac{d}{2}$

$\tan d = \frac{1/2\,c}{R-m}$; $\sin d = \frac{1/2\,c}{R}$

Excess of "l" over "c" $= l - c = l - 2R\cdot\sin d$.

Sum of deflection angles, $d_1+d_2+\dots d_n = \frac{\Delta}{2}$

EXAMPLE:

Given: $R = 50'$; $\Delta = 110°$ ($\theta = 1.9195$); $l = 50'$.

Required: L, l_1, d, d_1, c, & c_1.

Solution: $L = 50 \times 1.9195 = 95.98'$; $l_1 = 95.98 - 50 = 45.98'$

$d = 1718.873 \times 50/50 = 28°39'$

$d_1 = 1718.873 \times \frac{45.98}{50} = 26°21'$

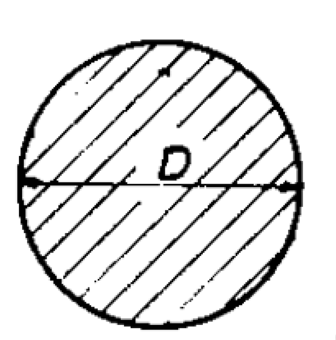
$c = 2R\sin 28°39' = 47.946'$

$c_1 = 2R\sin 26°21' = 44.385'$

TABLE A - DEFLECTIONS (d) & MIDDLE ORDINATES (m) FOR SUB-CHORDS.*

	CHORD \ RADIUS	10'	12'	15'	18'	20'	25'	30'	35'	40'	45'	50'	60'	70'	80'	90'	100'	120'	150'
DEFLECTION	5'	14°29'	12°01'	9°36'	7°59'	7°11'	5°44'	4°47'	4°06'	3°35'	3°11'	2°52'	2°23'	2°03'	1°47'	1°35'	1°26'	1°12'	0°57'
	10'	30°00'	24°37'	19°28'	16°08'	14°29'	11°32'	9°36'	8°13'	7°11'	6°23'	5°44'	4°47'	4°06'	3°35'	3°11'	2°52'	2°23'	1°55'
	20'		56°26'	41°49'	33°45'	30°00'	23°35'	19°28'	16°36'	14°29'	12°50'	11°32'	9°36'	8°13'	7°11'	6°23'	5°44'	4°47'	3°49'
	25'			56°27'	43°59'	38°41'	30°00'	24°37'	20°55'	18°13'	16°08'	14°29'	12°01'	10°17'	8°59'	7°59'	7°11'	5°59'	4°47'
	50'							56°27'	45°35'	38°41'	33°45'	30°00'	24°37'	20°55'	18°13'	16°08'	14°29'	12°01'	9°36'
M.	10'	1.34	1.09	0.86	0.71	0.64	0.51	0.42	0.36	0.31	0.28'	0.25	0.21	0.18	0.16	0.14	0.13	0.10	0.08
	20'		5.37	3.82	3.03	2.68	2.09	1.72	1.46	1.27	1.12	1.01	0.84	0.72	0.63	0.56	0.50	0.42	0.33

CIRCLE.



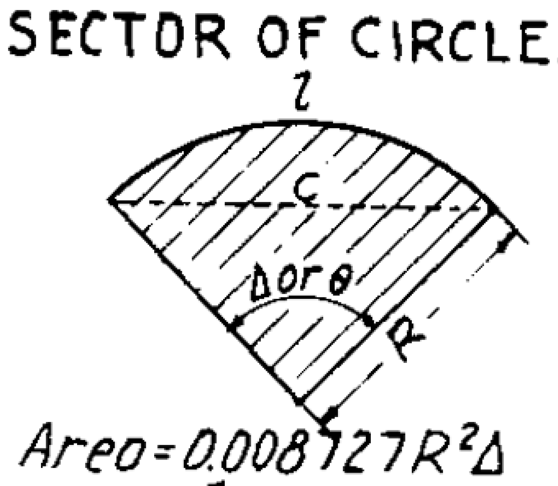
Area $= \pi R^2 = \frac{\pi D^2}{4}$

Circumference $= 2\pi R = \pi D$.

$R = \frac{Cir.}{2\pi} = \frac{D}{2} = \sqrt{\frac{Area}{\pi}}$

$D = 2R = cir./\pi$

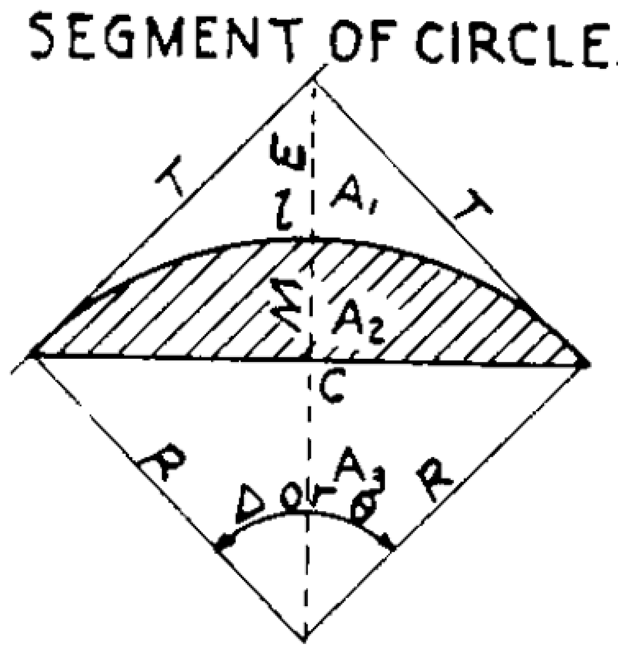
SECTOR OF CIRCLE.



Area $= 0.008727R^2\Delta$
$= 1/2\cdot l\cdot R = \pi R^2\frac{\Delta}{360}$
$= R^2\cdot\frac{\theta}{2}$

when $\Delta = 90°$: $A = 0.3927C^2$; $0.7854R^2$

SEGMENT OF CIRCLE.



$A_1 = R^2(\tan\frac{\Delta}{2} - \frac{\Delta\pi}{360}) = R(T - \frac{l}{2})$.

$A_2 = \frac{lR - c(R-M)}{2} = (\pi R^2\frac{\Delta}{360}) - [(R\sin\frac{\Delta}{2})(R\cos\frac{\Delta}{2})]$.

$A_2 = (\pi R^2\frac{\Delta}{360}) - 1/2\,c(R-M)$

$A_2 = 2/3\,Mc$ {Correct for parabolic segment, approximate for circular segment.

$A_2 = 1/2\,R^2(\theta - \sin\Delta) = 2/3\,Mc + \frac{M^3}{2c}$

$A_3 = 1/2\,R^2\sin\Delta = 1/2\,c(R-M) = (R\sin\frac{\Delta}{2})(R\cos\frac{\Delta}{2})$.

When $\Delta = 90°$: $A_1 = 0.2146R^2$
$= 1.2594E^2$

FIG. B - FORMULAS FOR AREAS.

* Adapted from Lefax Society Inc. Phila. Pa.

ROADS - TRANSITION CURVES*

FORMULAS:

$T_s = (R_c+p)\tan\frac{\Delta}{2}+k.$

$E_s = (R_c+p)\,\text{exsec}\frac{\Delta}{2}+p = \frac{R_c+p}{\cos\frac{\Delta}{2}} - R_c.$

$p = y_c - R_c(1-\cos\theta_s) = \frac{y_c}{4}$ (approx.).

$k = x_c - R_c\sin\theta_s = \frac{L_s}{2}$ (approx).

$\theta_s = \frac{L_s D_c}{200}$; $\theta = \left(\frac{L}{L_s}\right)^2\theta_s$

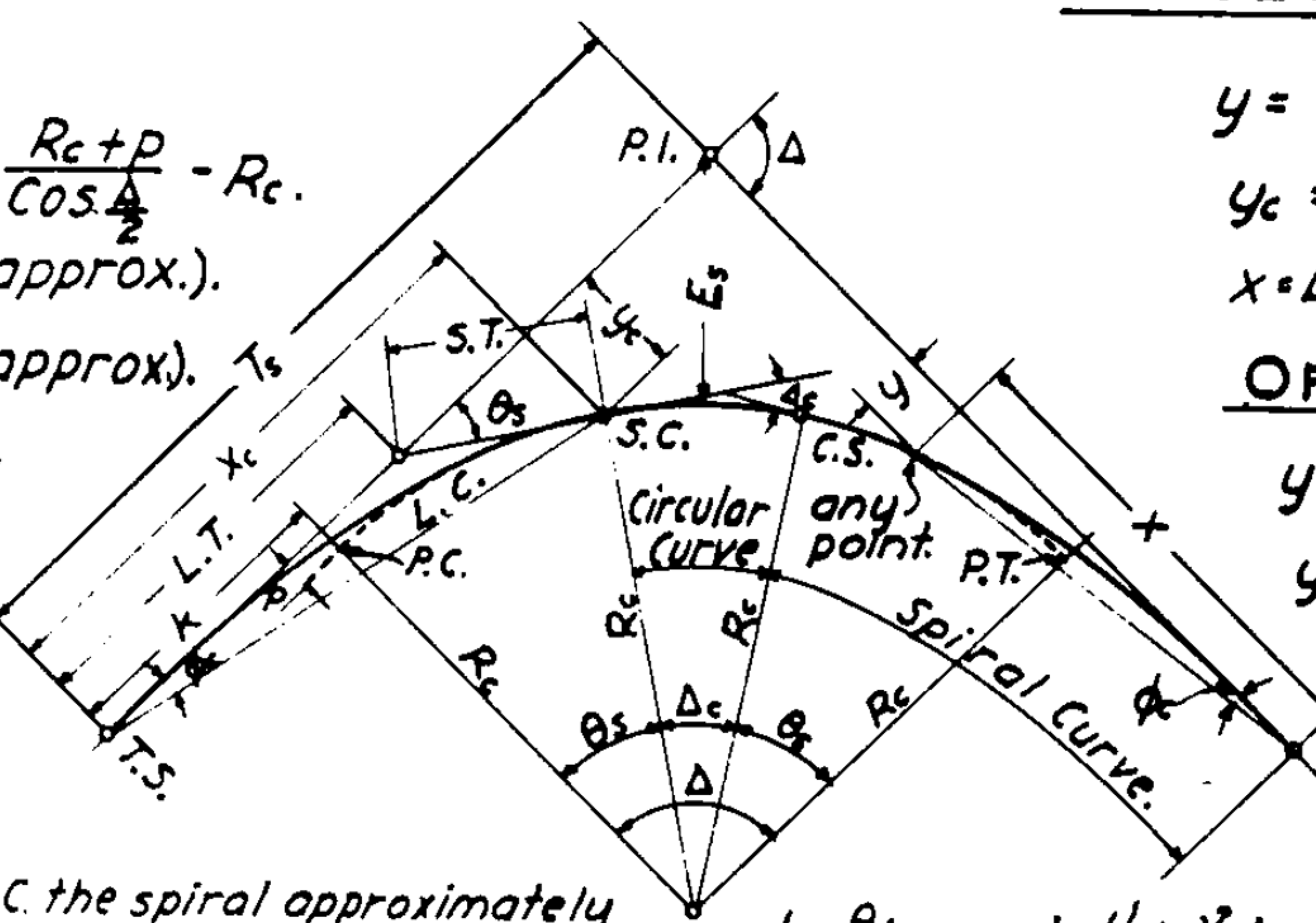
$\theta = \frac{L^2 D_c}{200 L_s}$

$L_c = \frac{100\,\Delta_c}{D_c}$; $L.C. = \frac{x_c}{\cos\phi_c}$

$\Delta_c = \Delta - \frac{L_s D_c}{100}$

$D = \frac{L}{L_s}D_c$

$D_c = \frac{200\,\theta_s}{L_s}$



NOTE: At the P.C. the spiral approximately bisects P.

$\phi_c = \theta/3 - c$; $\phi = (L/L_s)^2\phi_c$

OFFSETS TO "x" AND "y":

$y = \frac{L}{L_s}^3 y_c = L$ (y for $L_s = 1$).

$y_c = L_s$ (y for $L_s = 1$).

$x = L$ (x for $L_s = 1$); $x_c = L_s$ (x for $L_s = 1$).

OFFSETS TO 1/4 POINTS.

y at 1/4 point $= y_c/4^3$

y at 1/2 point $= y_c/2^3 = P/2$ (approx.)

y at 3/4 point $= y_c(4/3)^3$

TOTAL LENGTH OF CURVE.

T_s to S.T. $= 2L_s + 100\frac{\Delta_c}{D_c}$

NOTES: With L_s given or selected from Table "C" below, P, k, x, y, L, T, S.T., and L.C. may be computed for any spiral by multiplying functions for $L_s = 1$ in Table A, page 3-55 by L_s or L in feet. Interpolate for values of θ or θ_s between even degrees. For circular curve layout see page 3-46.
Circular curve may be omitted and curve made transitional throughout in which case S.C. and C.S. coincide at S.C.S., $\theta = \Delta/2$, $\Delta_c = 0$ and T_s & E_s are computed from Table A, page 3-56.

FIG. A - CIRCULAR CURVES WITH SPIRAL TRANSITIONS.

NOTATION

- R_c = Radius of the circular curve.
- P = Offset distance from tangent to the P.C. of the circular curve produced.
- k = Distance from T.S. to P.C. along tangent.
- T_s = Tangent distance.
- E_s = External distance.
- x_c, y_c = Coordinates from T.S. to S.C. & S.T. to C.S.
- θ = Spiral angle at any point on spiral.
- θ_s = Spiral angle at S.C. or C.S.
- L = Length of spiral, T.S. to any point on spiral.
- L_s = Length of spiral, T.S. to S.C. or S.T. to C.S.
- D_c = Degree of circular curve (arc definition).
- D = Degree of curve at any point on spiral.
- x, y = Coordinates from T.S. or S.T. to any point on spiral.
- ϕ_c = Deflection from tangent at T.S. to S.C.
- ϕ = Deflection from tangent at T.S., S.T. or any point on spiral to any other point on spiral.
- L.T., S.T. = Long tangent, short tangent.
- L.C. = Long chord of spiral transition.
- Δ = Intersection and central angle of entire curve.
- Δ_c = Intersection & central angle of circular curve.
- L_c = Length of circular curve, S.C. to C.S.

NOTE: The degree of curvature varies directly as the length, from zero curvature at T.S. to the maximum of Dc at the S.C. The spiral departs from the circular curve at the same rate as from the tangent.

SPIRAL LAYOUT (See page 3-54 also).

Method I: Deflections to even stations by formula $\phi = \theta/3 = 1/3\,\theta_s(L/L_s)^2$. Correct ϕ for c when $\theta > 20°$.

TABLE B "C" IN FORMULA, $\phi = \theta/3 - c$. (FOR CURVES WITH θ OVER 20°)

θ in degrees.	20	25	30	35	40	45	50
c in minutes.	0.4	0.8	1.4	2.2	3.4	4.8	5.6

Method II: - Offsets from tangent. Establish by measuring "x" distances from T.S. and "y" distances from tangent. Compute θ for each point and then compute "x" and "y" coordinates from Table A - p. 3-55, or use 1/4 point formulas above.

Method III: - Deflection angle from T.S. or S.T. to any point on spiral with coordinates "x" and "y" is the angle whose tangent = y/x.

Method IV: - Deflection angles from T.S. to points of 10 equal divisions (10 chord spiral) are: $0.01\phi_c$; $0.04\phi_c$; $0.16\phi_c$; $0.25\phi_c$; $0.36\phi_c$; $0.49\phi_c$; $0.64\phi_c$; $0.81\phi_c$ & ϕ_c.

TABLE C - MINIMUM TRANSITION LENGTHS.

D_c	30 M.P.H. L_s	40 M.P.H. L_s	50 M.P.H. L_s	60 M.P.H. L_s	70 M.P.H. L_s	D_c
1° 30'	150'	150'	150'	150'	150'	1°-30'
2°	"	"	"	"	200'	2°
2° 30'	"	"	"	"	250'	2° 30'
3°	"	"	"	"	300'	3°
3° 30'	"	"	"	200'	350'	3° 30'
4°	"	"	"	250'	400'	4°
5°	"	"	"	300'		
6°	"	"	200'	350'		
7°	"	"	250'			
8°-9°	"	"	300'			
10°-12°	"	200'				
13°-14°	"	250'				
15°-23°	"					
24°	200'					

Based on $L_s = \frac{1.6V^3}{R_c}$

Where: V = 0.75 Design Speed in M.P.H. Min. L_s = 150 ft.

*Adapted from Transition Curves for Highways by Joseph Barnett, P.R.A.

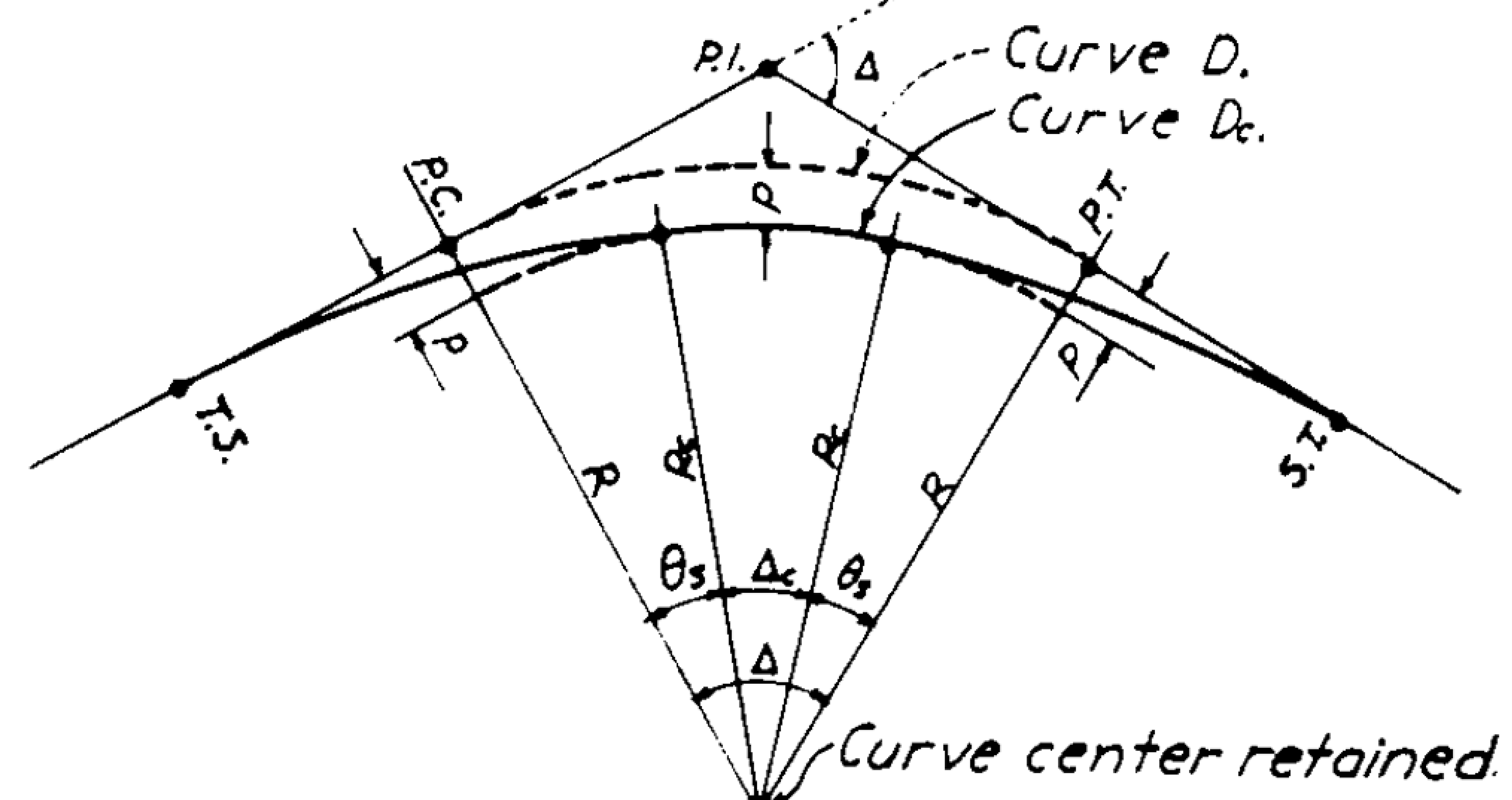
ROADS-TRANSITION CURVES-GENERAL PROBLEMS

INSERTION OF SPIRALS INTO EXISTING ALIGNMENT OF CIRCULAR CURVES.

L_s = Length of spiral - select from Table C-page 3-52.

θ_s = Spiral angle = $\frac{L_s D_c}{200}$, where D_c = Degree of curvature (arc definition).

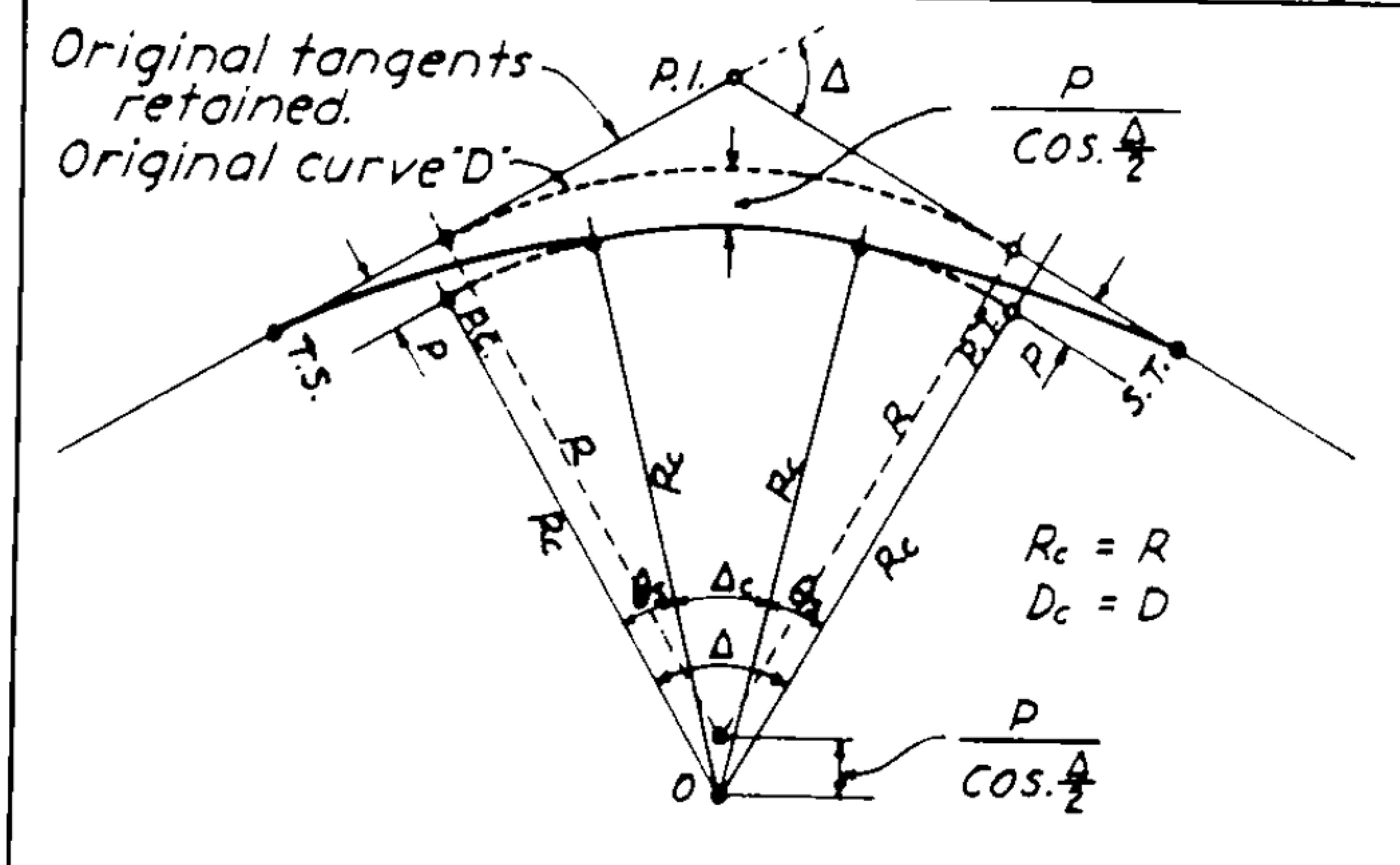
P = Offset of curve at P.C. to permit spiral introduction-from Table - p. 3-55, knowing θ_s.



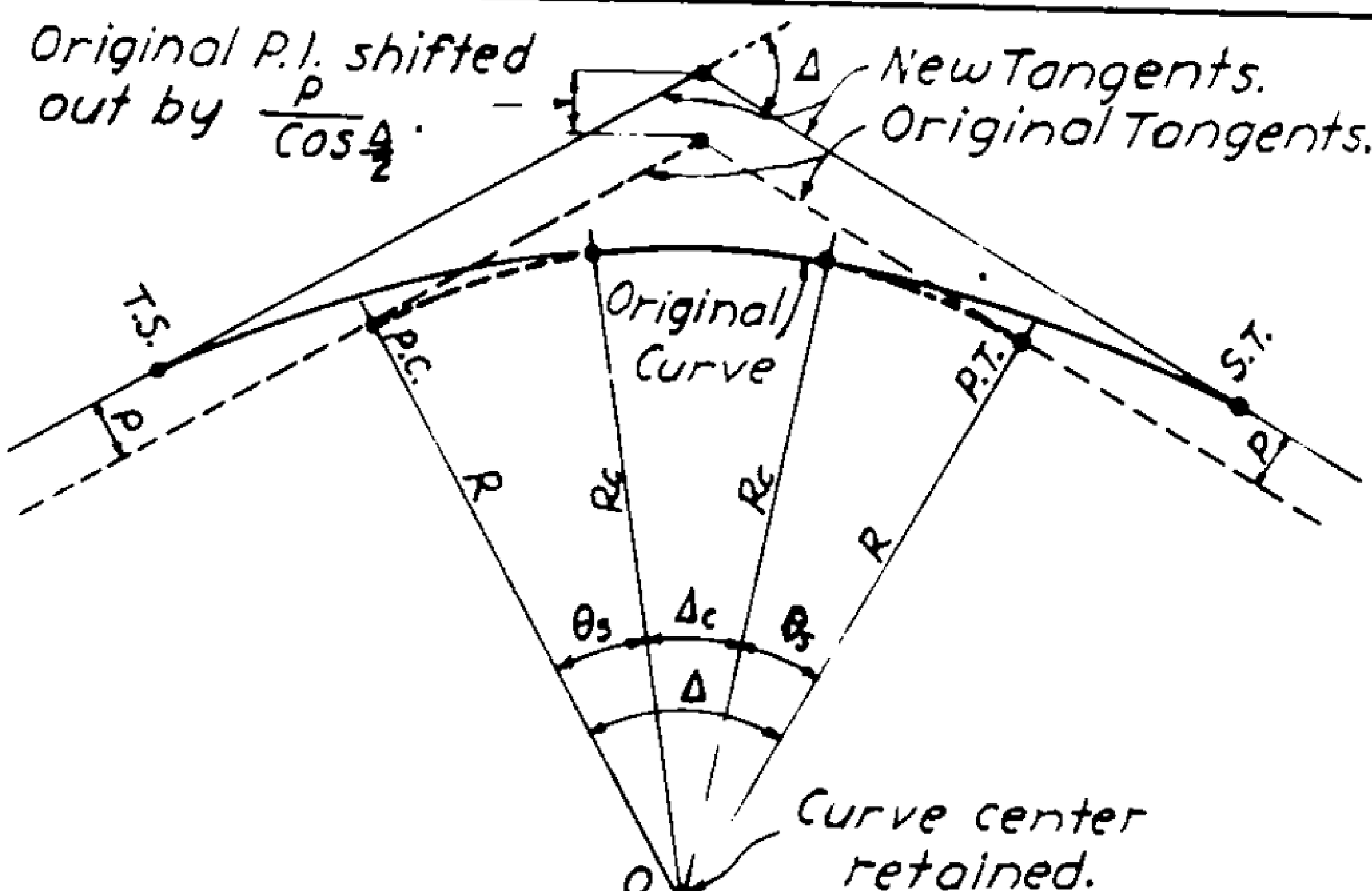
CASE I - Radius of original circular curve reduced by value of "P" to provide space to insert spiral transition.

1ST Trial: Assume $D_c = D$, find trial "P" as above.

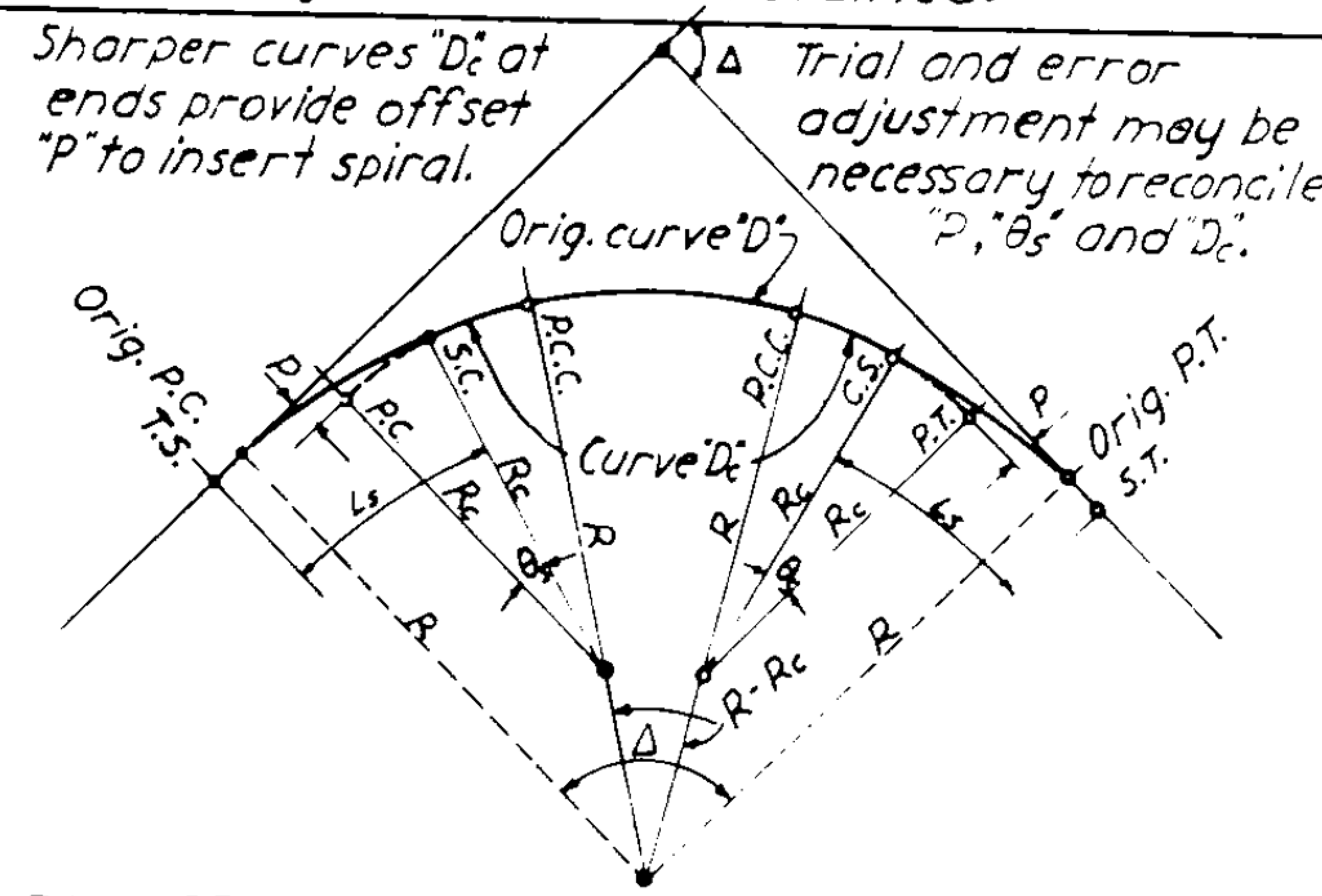
2ND Trial: Compute $D_c = \frac{5727.58}{R_c}$, find correct "P."



CASE II - Radius of original curve retained and curve center "O" shifted inward.
Note: Degree of curve retained.

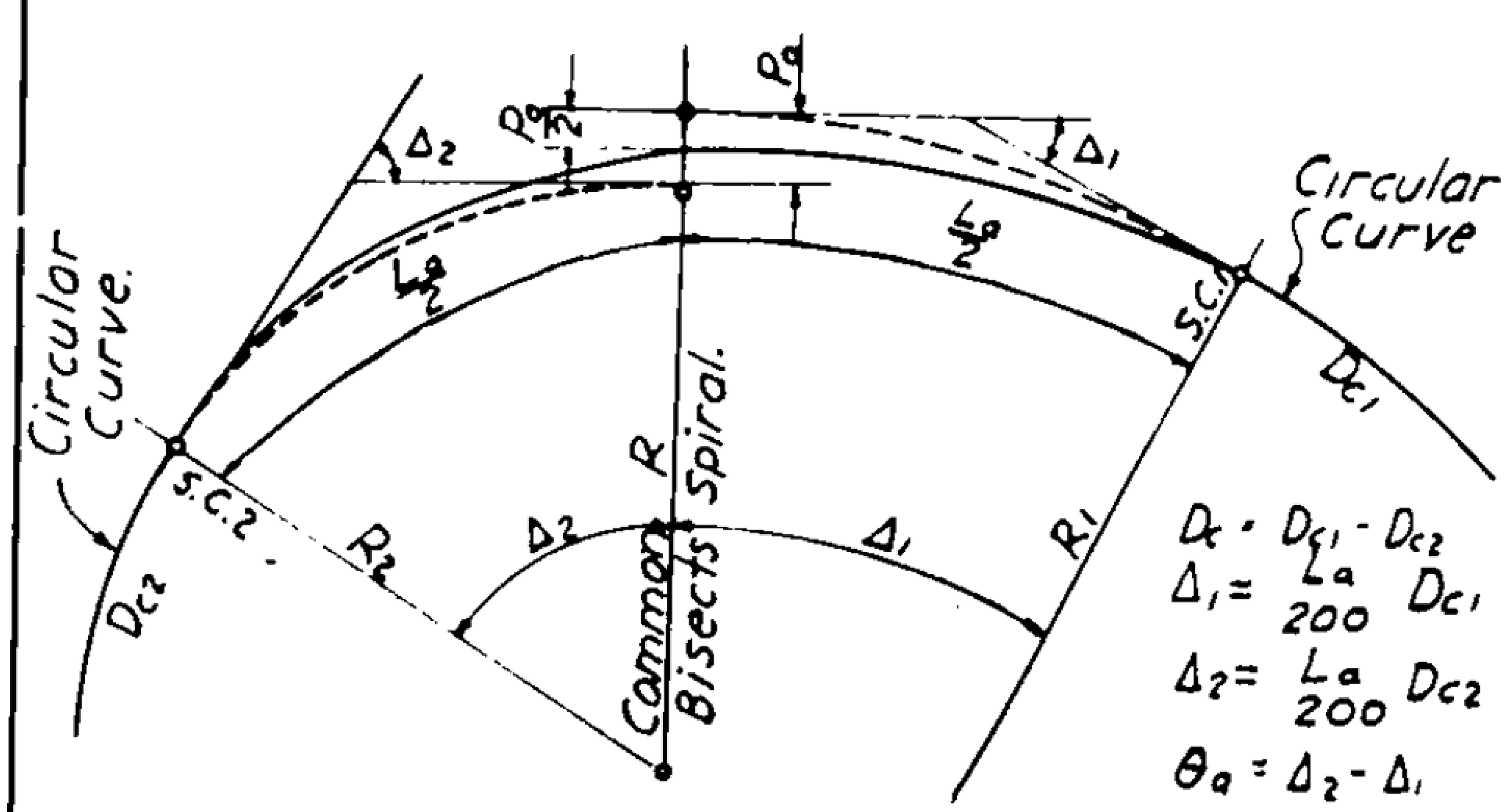


CASE III - Original circular curve location retained and tangents shifted outward to insert spiral.



CASE IV - Original alignment retained as as closely as possible by compounding circular curve at both ends.

θ_a = Equivalent spiral angle. Use in Table page 3-55 to find "P_a".



CASE V -
To insert a spiral in a compound curve.

Given: R_1, R_2, T, P_1 & P_2.

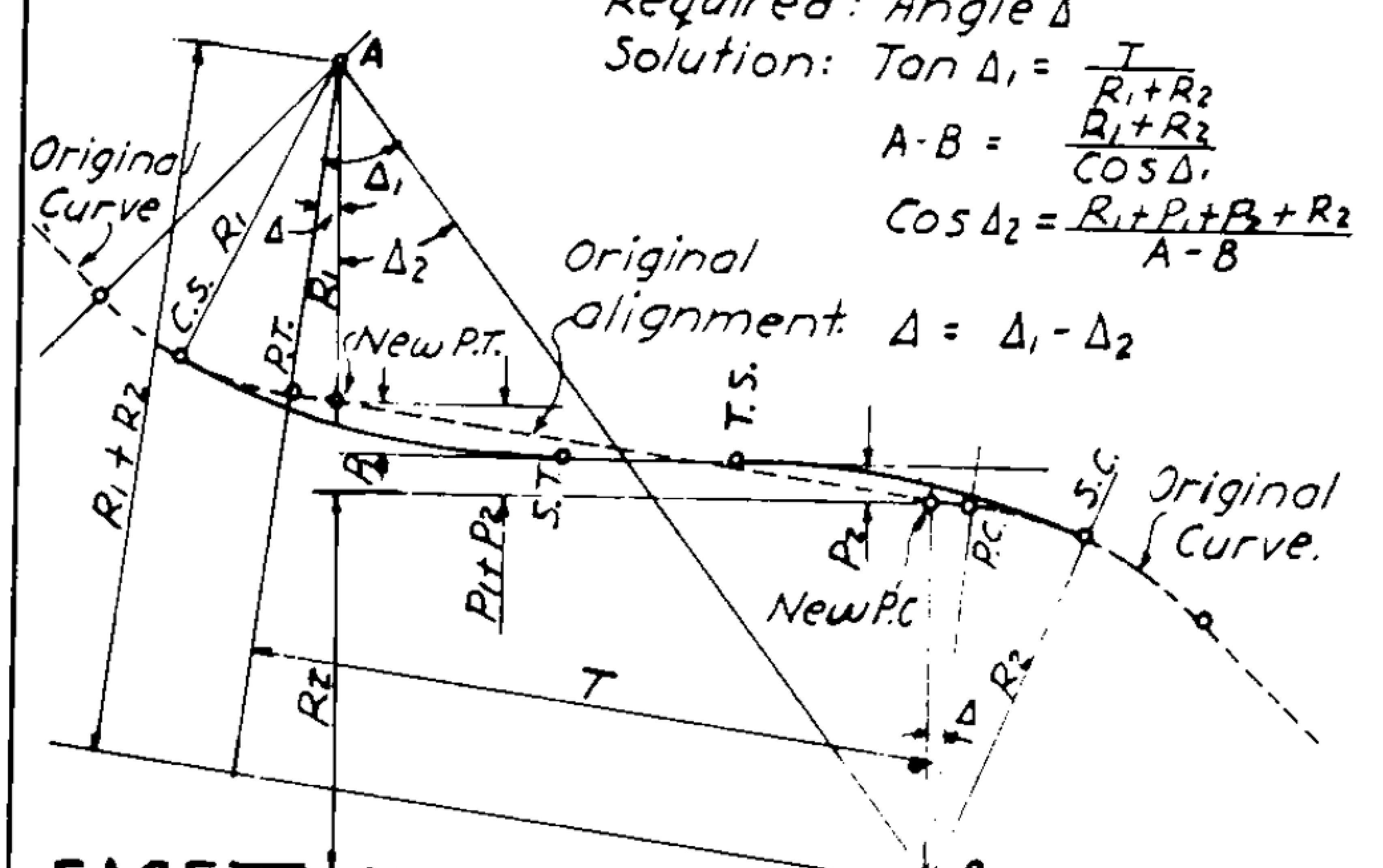
Required: Angle Δ

Solution: $\tan \Delta_1 = \frac{T}{R_1 + R_2}$

$A\text{-}B = \frac{R_1 + R_2}{\cos \Delta_1}$

$\cos \Delta_2 = \frac{R_1 + P_1 + P_2 + R_2}{A\text{-}B}$

$\Delta = \Delta_1 - \Delta_2$

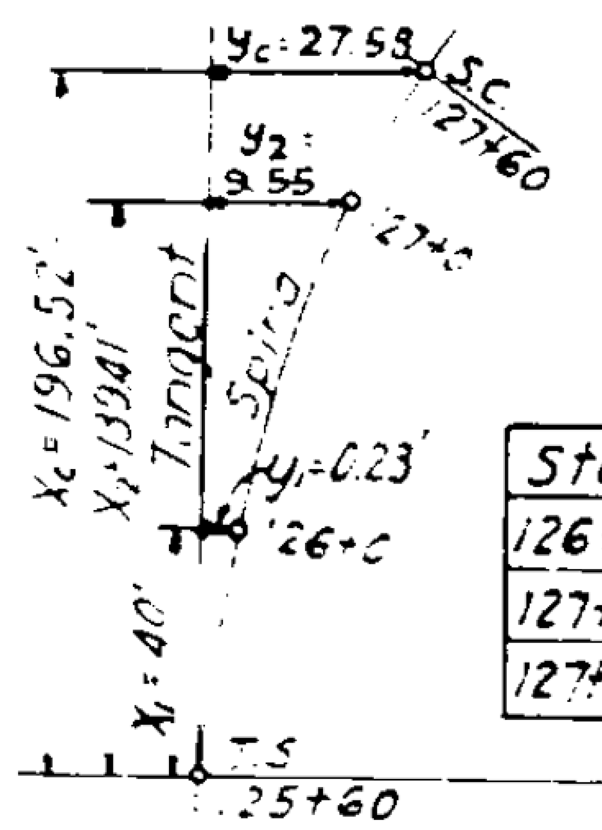


CASE VI - To insert spirals between simple reverse curves separated by a tangent.

ROADS-TRANSITION CURVES-PROPERTIES & EXAMPLES *

PROPERTIES OF SPIRAL.

1. Offsets, y, vary as the cube of L, or length of spiral $\therefore$ y at any point $= \left(\frac{L}{L_s}\right)^3 y_c$. See Fig. A.
2. Spiral angle "θ" varies as L^2 $\therefore$ θ at any point on spiral $= \left(\frac{L}{L_s}\right)^2 \theta_s$.
3. Deflection angle "ϕ" varies as L^2 $\therefore$ $\phi = \left(\frac{L}{L_s}\right)^2 \phi_c$.
   $\phi_c = \frac{1}{3}\theta_s - c$, c being a constant, see Table B - p. 3-52 (May be neglected for ordinary problems).
4. "D", or degree of curve of spiral at any point, varies directly as L $\therefore$ $D = \frac{L}{L_s} D_c$.
5. Spiral bisects "P" very nearly and "k" approximately $= \frac{1}{2} L_s$ $\therefore$ Offset from circular curve or tangent to mid point of spiral is $\frac{1}{2}P$ very nearly.
6. Spiral departs from the circular curve between S.C. and P.C. at the same rate as from the tangent. $\therefore$ Radial offsets from circular curve between S.C. and P.C. to the spiral are the same as perpendicular offsets from the tangent between T.S. and P.C.



Given: Spiral $L_s = 200'$; $\theta_s = 24°$;
T. S. at Sta. 125+60.
Required: Offsets to even stations.
Solution: Compute θ and read x & y for $L_s = 1$ from Table - p. 3-55

Sta.	L	θ	x, L_s=1	y, L_s=1	x	y
126+0	40	0°58'	0.99997	0.00559	40.0	0.22
127+0	140	11°46'	0.99578	0.06821	139.41	9.55
127+60	200	24°0'	0.98 260	0.13789	196.52	28.58

FIG. A - OFFSETS TO EVEN STATIONS.

Given: Spiral, $L_s = 200'$; $\theta_s = 24°$.
Required: Offsets to 1/4 points.
Solution: From Fig. A; $y_c = 27.58'$
By formula, y at any point $= \left(\frac{L}{L_s}\right)^3 y_c$

At 1/4 points, $y = 27.58 \times \frac{1}{64} = 0.43'$.
At 1/2 points, $y = 27.58 \times \frac{1}{8} = 3.45'$.

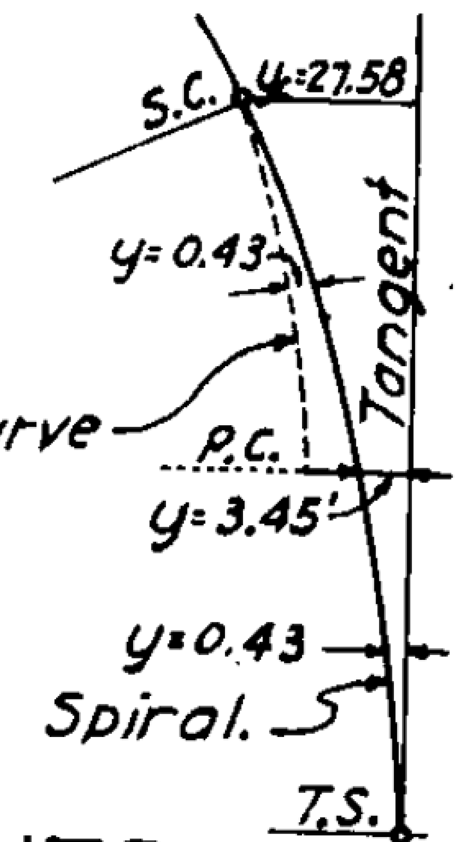
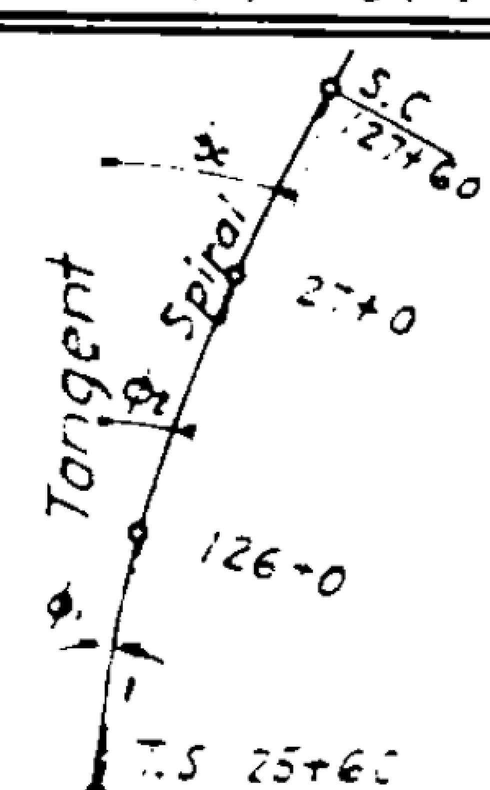


FIG. B - OFFSETS TO 1/4 POINTS.



Given: Spiral with $L_s = 200'$ and $\theta_s = 24°$
Required: Deflection angles ϕ_1 to Sta. 126+0; ϕ_2 to Sta. 127+0; ϕ_c to Sta. 127+60.
Solution: By formulas, $\phi_c = \frac{\theta_s}{3} - c$ and $\phi = \frac{1}{3}\left(\frac{L}{L_s}\right)^2 \theta_s - c$.

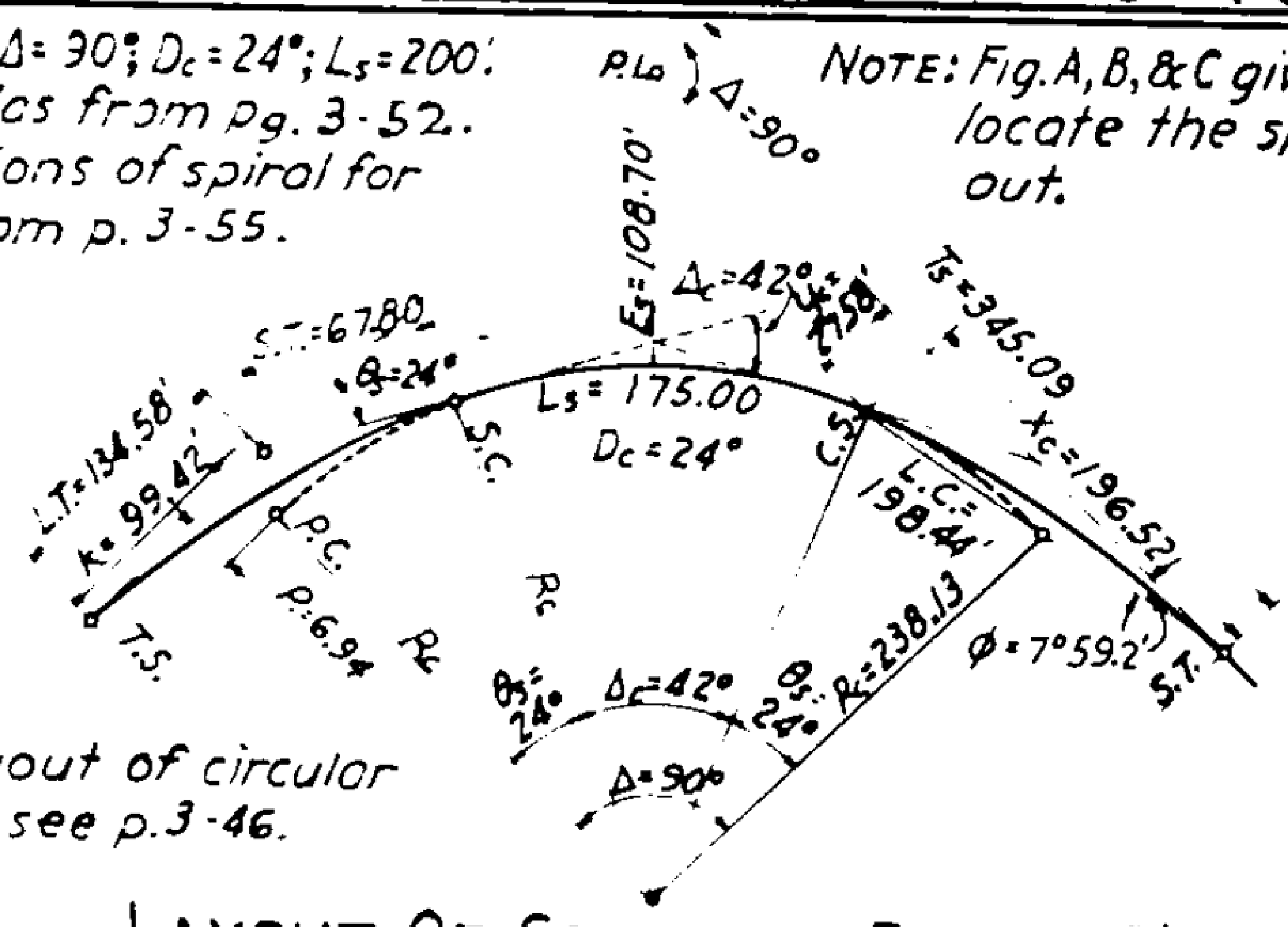
Sta. 127+60: $\phi_c = 24/3 - 0.8 = 7.9866° = 7° 69.2'$
Sta. 126+00: $\phi_1 = \left(\frac{L}{L_s}\right)^2 \phi_c = \left(\frac{40}{200}\right)^2 \times 7.9866 = 0.3195° = 0° 19'$
Sta. 127+00: $\phi_2 =$ " $\left(\frac{140}{200}\right)^2 \times 7.9866 = 3.9134° = 3° 55'$

Layout: With transit at T.S., foresight along tangent with vernier at 0°. Turn ϕ_1 and measure 40 ft. to Sta. 126+0. Turn ϕ_2 and measure 100 ft. from Sta. 126+0 to Sta. 127+0. Turn ϕ_c and measure 60' from Sta. 127+0 to S.C.

FIG. C - DEFLECTIONS TO EVEN STATIONS.

Given: $\Delta = 30°$; $D_c = 24°$; $L_s = 200'$.
Formulas from pg. 3-52.
Functions of spiral for $L_s = 1$ from p. 3-55.

NOTE: Fig. A, B, & C give all dimensions usually necessary to plot or locate the spiral. The following example is a curve fully worked out.



REQUIRED	FORMULA	SOLUTION
θ_s	$L_s D_c \div 200$	$\theta_s = 24°$
Δ_c	$\Delta - (L_s D_c \div 100)$	$\Delta_c = 42°$
L_c	$100 \Delta_c \div D_c$	$L_c = 175.00$
ϕ_c	$\frac{1}{3}\theta_s - c$	$\phi_c = 7°59.2'$
y_c	$(y$ for $L_s = 1) \cdot L_s$	$y_c = 27.58'$
x_c	$(x$ for $L_s = 1) \cdot L_s$	$x_c = 196.52'$
P	$y_c - R_c(1 - \cos\theta_s)$	$P = 6.94'$
k	$x_c - R_c \sin\theta_s$	$k = 99.42'$
E_s	$(R_c + P)\,\mathrm{exsec}\frac{\Delta}{2} + P$	$E_s = 108.70'$
T_s	$(R_c + P)\tan\frac{\Delta}{2} + k$	$T_s = 345.09'$
L.T.	(L.T. for $L_s = 1$) L_s; $\theta = 24°$	L.T. = 134.58'
S.T.	(S.T. for $L_s = 1$) L_s; $\theta = 24°$	S.T. = 67.80'
L.C.	(L.C. for $L_s = 1$) L_s; $\theta = 24°$	L.C. = 198.44

For layout of circular curve - see p. 3-46.

LAYOUT OF CONTROL POINTS.**

Establish T.S. by measuring k from P.O.T. normal to P.C. or by T_s from P.I. Establish S.C. by L.T., θ_s and S.T. or by x_c and y_c from T.S. or by ϕ_c and L.C. from T.S.

FIG. D - COMPUTATIONS FOR SPIRAL TRANSITIONS TO CIRCULAR CURVES.

* Ref. - Transition Curves for Highways by Joseph Barnett, P.R.A.

** Adapted from O'Rourke, General Engineering Handbook, Mc Graw-Hill.

ROADS — FUNCTIONS OF TRANSITION FOR $L_s = 1$*

Enter Table with value of θ or $θ_s$ and multiply function by L or L_s. See page 3-54 for use of Table.

θ	p	k	x	y	L.T.	S.T.	L.C.	θ
0°	.00000	.50000	1.00000	.00000	.66667	.33333	1.00000	0°
1°	.00146	.49999	.99997	.00582	.66668	.33334	.99999	1°
2°	.00291	.49998	.99988	.01163	.66671	.33337	.99995	2°
3°	.00435	.49995	.99973	.01745	.66676	.33342	.99988	3°
4°	.00581	.49992	.99951	.02326	.66684	.33349	.99978	4°
5°	.00727	.49987	.99924	.02907	.66693	.33358	.99966	5°
6°	.00872	.49982	.99890	.03488	.66705	.33368	.99951	6°
7°	.01018	.49975	.99851	.04068	.66719	.33381	.99934	7°
8°	.01163	.49967	.99805	.04648	.66735	.33395	.99913	8°
9°	.01308	.49959	.99754	.05227	.66753	.33412	.99890	9°
10°	.01453	.49949	.99696	.05805	.66773	.33430	.99865	10°
11°	.01598	.49939	.99632	.06383	.66796	.33451	.99836	11°
12°	.01743	.49927	.99562	.06959	.66821	.33473	.99805	12°
13°	.01887	.49914	.99486	.07535	.66847	.33498	.99771	13°
14°	.02032	.49901	.99405	.08110	.66877	.33524	.99735	14°
15°	.02176	.49886	.99317	.08684	.66908	.33553	.99696	15°
16°	.02320	.49870	.99223	.09257	.66941	.33583	.99654	16°
17°	.02465	.49854	.99123	.09828	.66977	.33615	.99609	17°
18°	.02608	.49836	.99018	.10398	.67015	.33650	.99562	18°
19°	.02752	.49817	.98906	.10967	.67055	.33687	.99512	19
20°	.02896	.49798	.98788	.11535	.67097	.33725	.99460	20°
21°	.03040	.49777	.98665	.12101	.67142	.33766	.99404	21°
22°	.03183	.49755	.98536	.12665	.67189	.33809	.99346	22°
23°	.03326	.49733	.98401	.13228	.67238	.33854	.99286	23°
24°	.03469	.49709	.98260	.13789	.67290	.33901	.99222	24°
25°	.03611	.49684	.98113	.14348	.67344	.33950	.99157	25°
26°	.03753	.49658	.97960	.14905	.67400	.34001	.99088	26°
27°	.03896	.49632	.97802	.15461	.67459	.34055	.99017	27°
28°	.04037	.49605	.97638	.16014	.67520	.34111	.98943	28°
29°	.04179	.49576	.97469	.16565	.67584	.34169	.98866	29°
30°	.04321	.49546	.97293	.17114	.67650	.34229	.98787	30°
31°	.04462	.49516	.97112	.17661	.67719	.34292	.98705	31°
32°	.04602	.49484	.96926	.18206	.67790	.34356	.98621	32°
33°	.04743	.49452	.96733	.18748	.67863	.34424	.98534	33°
34°	.04883	.49419	.96536	.19288	.67939	.34493	.98444	34°
35°	.05023	.49385	.96332	.19826	.68018	.34565	.98351	35°
36°	.05163	.49349	.96124	.20361	.68100	.34640	.98257	36°
37°	.05301	.49313	.95910	.20893	.68184	.34717	.98159	37°
38°	.05441	.49276	.95690	.21423	.68271	.34796	.98059	38°
39°	.05579	.49238	.95466	.21949	.68360	.34878	.97956	39°
40°	.05718	.49199	.95235	.22473	.68452	.34962	.97851	40°
41°	.05855	.49159	.95000	.22994	.68547	.35049	.97743	41°
42°	.05993	.49118	.94759	.23513	.68645	.35139	.97632	42°
43°	.06130	.49075	.94513	.24028	.68746	.35232	.97519	43°
44°	.06267	.49032	.94262	.24540	.68850	.35327	.97404	44°
45°	.06403	.48990	.94005	.25049	.68957	.35424	.97285	45°
46°	.06538	.48945	.93744	.25555	.69066	.35525	.97165	46°
47°	.06674	.48900	.93477	.26057	.69179	.35629	.97041	47°
48°	.06809	.48852	.93206	.26556	.69295	.35735	.96916	48°
49°	.06944	.48805	.92930	.27052	.69414	.35844	.96787	49°
50°	.07078	.48757	.92649	.27544	.69536	.35957	.96656	50°

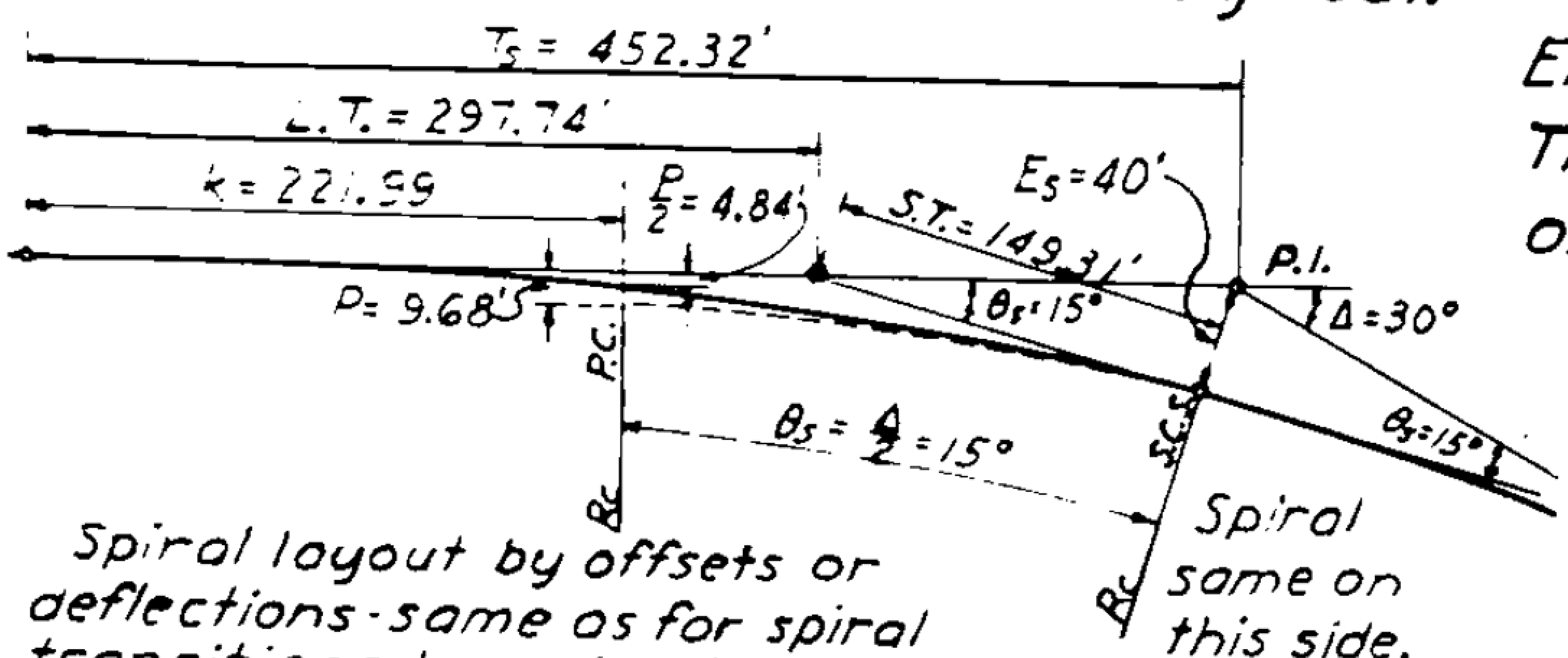
* Adapted from Transition Curves for Highways by Joseph Barnett, P.R.A.

ROADS - FUNCTIONS OF CURVES TRANSITIONAL THROUGHOUT

TABLE A- TANGENTS AND EXTERNALS FOR $L_s = 1$*

Δ°	T_s	E_s	Δ°	T_s	E_s	Δ°	T_s	E_s
6°	1.00064	0.01747	38°	1.02682	0.11599	70°	1.10214	0.24203
7	1.00087	0.02040	39	1.02832	0.11936	71	1.10561	0.24681
8	1.00114	0.02332	40	1.02987	0.12275	72	1.10917	0.25167
9	1.00144	0.02625	41	1.03146	0.12617	73	1.11281	0.25660
10	1.00178	0.02918	42	1.03310	0.12962	74	1.11654	0.26161
11	1.00216	0.03213	43	1.03479	0.13309	75	1.12036	0.26669
12	1.00257	0.03507	44	1.03653	0.13660	76	1.12427	0.27186
13	1.00302	0.03802	45	1.03831	0.14012	77	1.12828	0.27710
14	1.00350	0.04098	46	1.04015	0.14370	78	1.13240	0.28244
15	1.00402	0.04396	47	1.04204	0.14730	79	1.13661	0.28786
16	1.00458	0.04693	48	1.04399	0.15094	80	1.14092	0.29337
17	1.00518	0.04992	49	1.04598	0.15460	81	1.14535	0.29898
18	1.00581	0.05292	50	1.04804	0.15831	82	1.14988	0.30468
19	1.00648	0.05593	51	1.05014	0.16206	83	1.15453	0.31048
20	1.00719	0.05895	52	1.05230	0.16584	84	1.15930	0.31639
21	1.00794	0.06198	53	1.05452	0.16966	85	1.16418	0.32241
22	1.00873	0.06502	54	1.05680	0.17352	86	1.16919	0.32854
23	1.00955	0.06808	55	1.05913	0.17742	87	1.17433	0.33478
24	1.01042	0.07115	56	1.06153	0.18137	88	1.17960	0.34115
25	1.01132	0.07424	57	1.06399	0.18536	89	1.18500	0.34763
26	1.01226	0.07734	58	1.06651	0.18940	90	1.19054	0.35425
27	1.01324	0.08045	59	1.06909	0.19348	91	1.19623	0.36099
28	1.01427	0.08358	60	1.07174	0.19762	92	1.20207	0.36788
29	1.01533	0.08674	61	1.07446	0.20181	93	1.20806	0.37490
30	1.01644	0.08990	62	1.07724	0.20604	94	1.21421	0.38207
31	1.01758	0.09309	63	1.08010	0.21034	95	1.22052	0.38940
32	1.01877	0.09630	64	1.08302	0.21468	96	1.22700	0.39688
33	1.02000	0.09952	65	1.08602	0.21908	97	1.23366	0.40453
34	1.02128	0.10277	66	1.08909	0.22355	98	1.24050	0.41234
35	1.02260	0.10604	67	1.09223	0.22807	99	1.24753	0.42034
36	1.02396	0.10933	68	1.09546	0.23266	100	1.25475	0.42852
37	1.02537	0.11265	69	1.09876	0.23731			

CASE VII: Given Δ and an external or tangent distance, to determine a curve transitional throughout.



Spiral layout by offsets or deflections - same as for spiral transitions to a circular curve.

FIG. B

Enter Table A at known Δ and read T_s & E_s values. Then $L_s = E_s / E_s \text{ value}$ and $T_s = L_s \cdot \text{Tangent value}$, or $L_s = T_s / T_s \text{ value}$ and $E_s = L_s \cdot \text{External value}$.

EXAMPLE

Given: Δ = 30° and E_s = 40'.

Required: L_s, T_s, θ_s, L.T., S.T., D_c, P and k.

Solution: $L_s = 40 \div 0.08990 = 444.9'$ say 445'

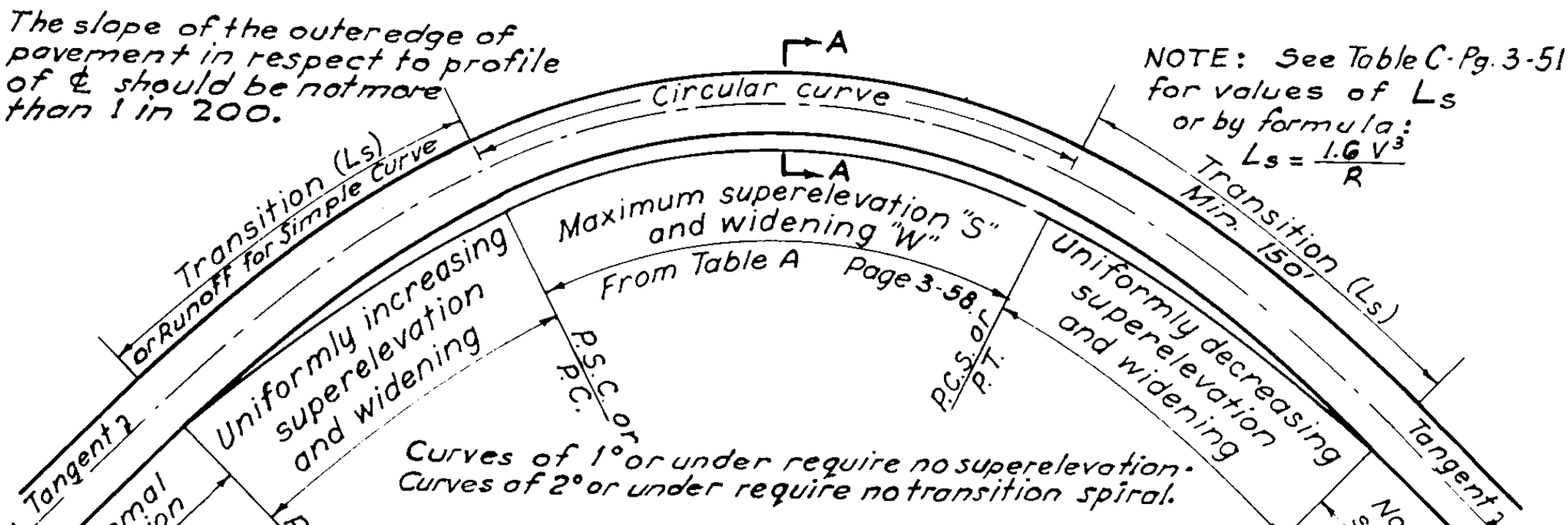
$T_s = 1.01644 \times 445 = 452.32'$. $\theta_s = \frac{\Delta}{2} = 15°$. $D_c = \frac{200\theta_s}{L_s} = 6.47'$

L.T. $\doteq 0.66908 \times 445 = 297.74'$. S.T. $= 0.33553 \times 445 = 149.31'$

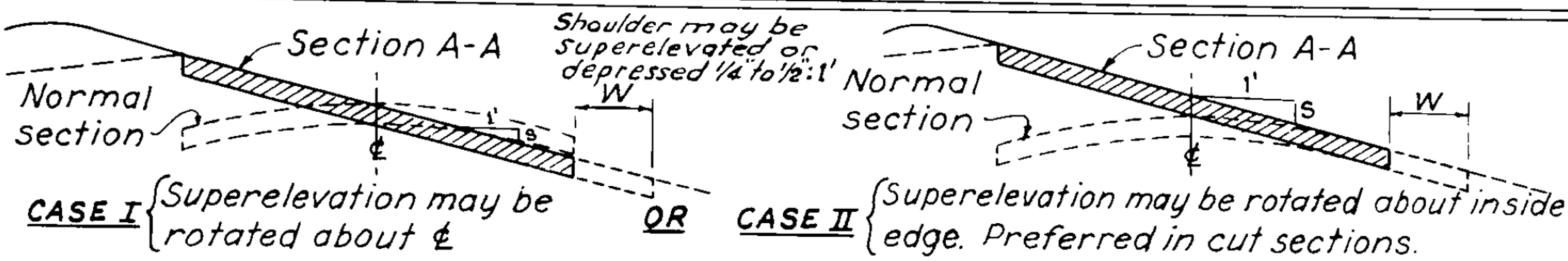
P $= 0.02176 \times 445 = 9.68'$. k $\doteq 498.86 \times 445 = 221.99'$.

*Adapted from Transition Curves for Highways by Joseph Barnett, P. R. A.

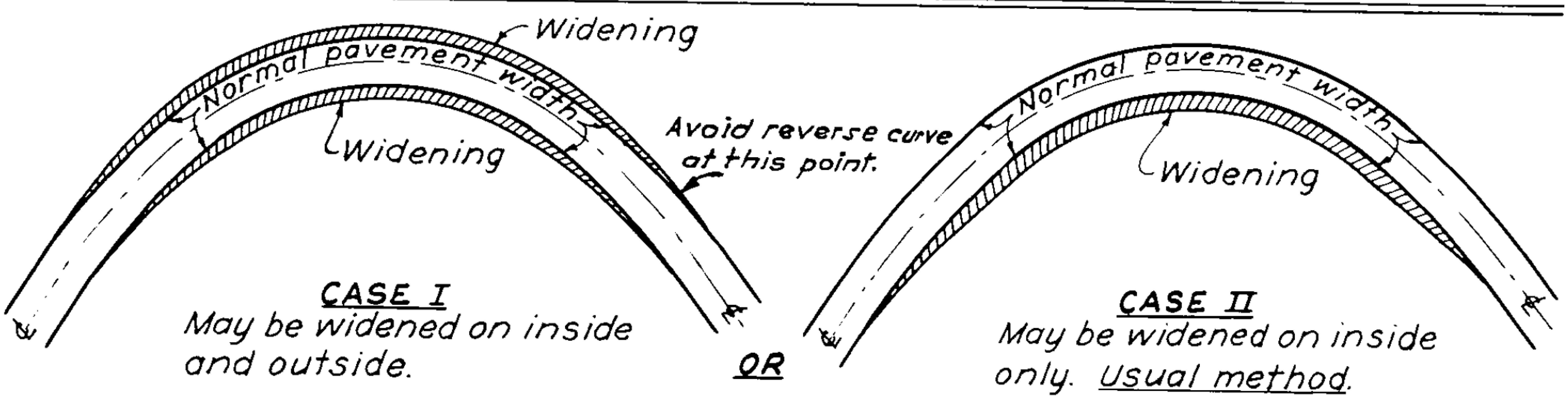
ROADS – SUPERELEVATION & WIDENING-1



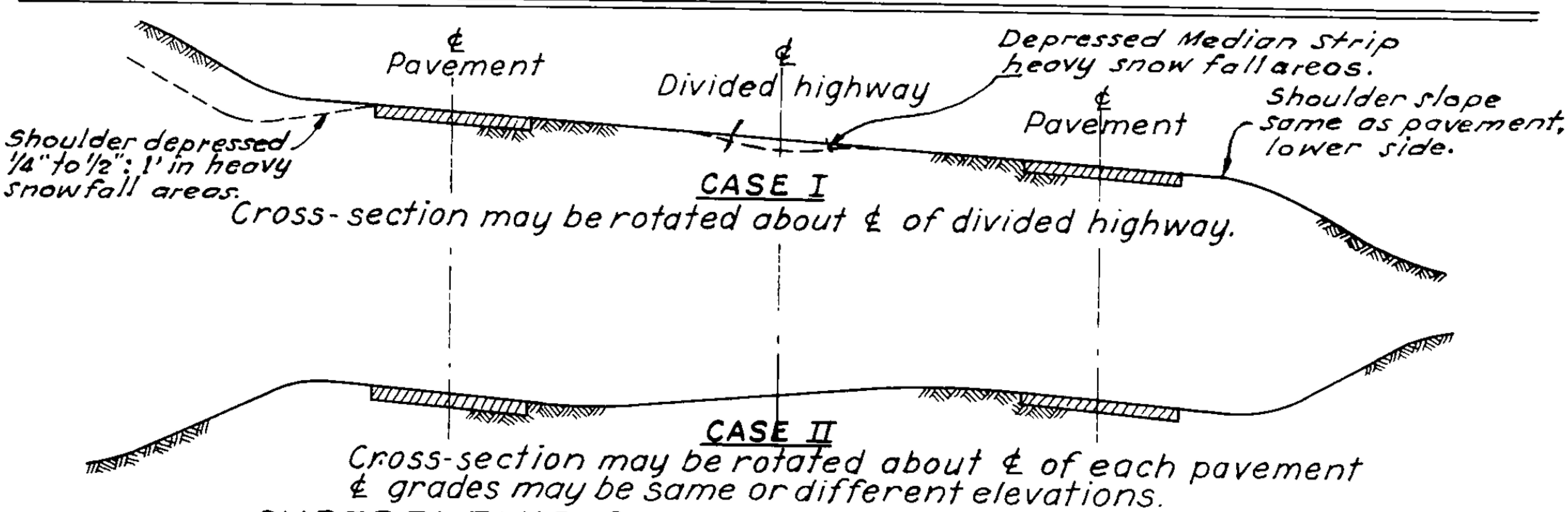
PLAN OF SUPERELEVATION AND WIDENING



SUPERELEVATION – SECTIONS



WIDENING-PLAN



SUPERELEVATION ON DIVIDED HIGHWAYS

Use method suited to local conditions and drainage.

Ref.: A Policy on Highway Types & Design Standard for Highways by A.A.S.H.O.

ROADS – SUPERELEVATION & WIDENING-2

TABLE A – REQUIRED SUPERELEVATION AND WIDENING *

R	D	DESIGN SPEED 30 M.P.H. S	W	40 M.P.H. S	W	50 M.P.H. S	W	60 M.P.H. S	W	70 M.P.H. S	W	80 M.P.H. S	W	90 M.P.H. S	W	100 M.P.H. S	W
5729.58	1	.01	—	.01	—	.02	—	.02	—	.03	—	.04	2	.05	2	.07	2
2864.79	2	.01	—	.02	—	.03	—	.05	—	.06	—	.08	2	.10	2	.125	2
1909.86	3	.02	—	.03	—	.05	—	.07	—	.09	—	.125	2	.125	2		
1432.39	4	.02	—	.04	—	.06	—	.09	—	.10	2						
1145.92	5	.03	—	.05	—	.08	—	.10	2								
954.93	6	.03	—	.06	—	.10	2	.10	2								
818.51	7	.04	—	.07	2	.10	2										
716.20	8	.05	2	$\boxed{.08}$	2	.10	2										
636.62	9	.05	2	.09	2	.10	3										
572.96	10	.06	2	.10	2												
520.87	11	.06	2	.10	3												
477.46	12	.07	3	.10	3												
440.74	13	.07	3	.10	3												
409.26	14	.08	3	.10	3												
381.97	15	.09	3														
358.10	16	.09	3														
337.03	17	.10	3														
318.31	18	.10	3														
301.56	19	.10	3														
286.48	20	.10	3														
272.84	21	.10	3														
260.44	22	.10	3														
249.11	23	.10	4														
238.73	24	.10	4														

LEGEND

R = radius of curve in feet
D = degree of curve
S = superelevation in feet per foot of width (For conversion; .01' = 1/8")
W = total widening in feet for 22'- 2 lane pavement

Based on formula for superelevation:

$$S = 0.067\frac{V^2}{R} - F$$ in which

S = superelevation in feet per foot
V = 3/4 design speed m.p.h.
R = radius of curve in feet
F = Side Friction Factor = 0.16 for 60 m.p.h. & less, 0.14 for 70 m.p.h.

Example

Given:
Design speed 40 m.p.h. and 8° curve

Required:
S - superelevation in feet per foot

Solution:
By table S = 0.08'

NOTES: 0.10 foot per foot is maximum superelevation in areas subject to ice and sleet. (0.08 per A.A.S.H.O.)

A maximum superelevation of 0.125 foot per foot is sometimes used in areas not subject to ice or sleet. (0.12 per A.A.S.H.O.)

For circular curves provide full superelevation and widening from P.C. to P.T. with minimum transition of at least 150 feet.

For roads wider than 22 feet reduce figures in table by width minus 22 feet, i.e.; a 9° curve on a normally 24 foot width, 2 lane, 50 m.p.h. road would be widened 3'-(24-22) or 1 foot.

For roads narrower than 22 feet increase figures in table by 22 feet minus width, i.e.; an 8° curve on a normally 20 foot width, 2 lane, 40 m.p.h. road would be widened 2+(22-20) or 4 feet.

The Public Roads Administration recommends no widening of curves flatter than 4° on pavements designed for 70 m.p.h, 5° for 60 m.p.h., 7° for 40 m.p.h. and 8° for 30 m.p.h.

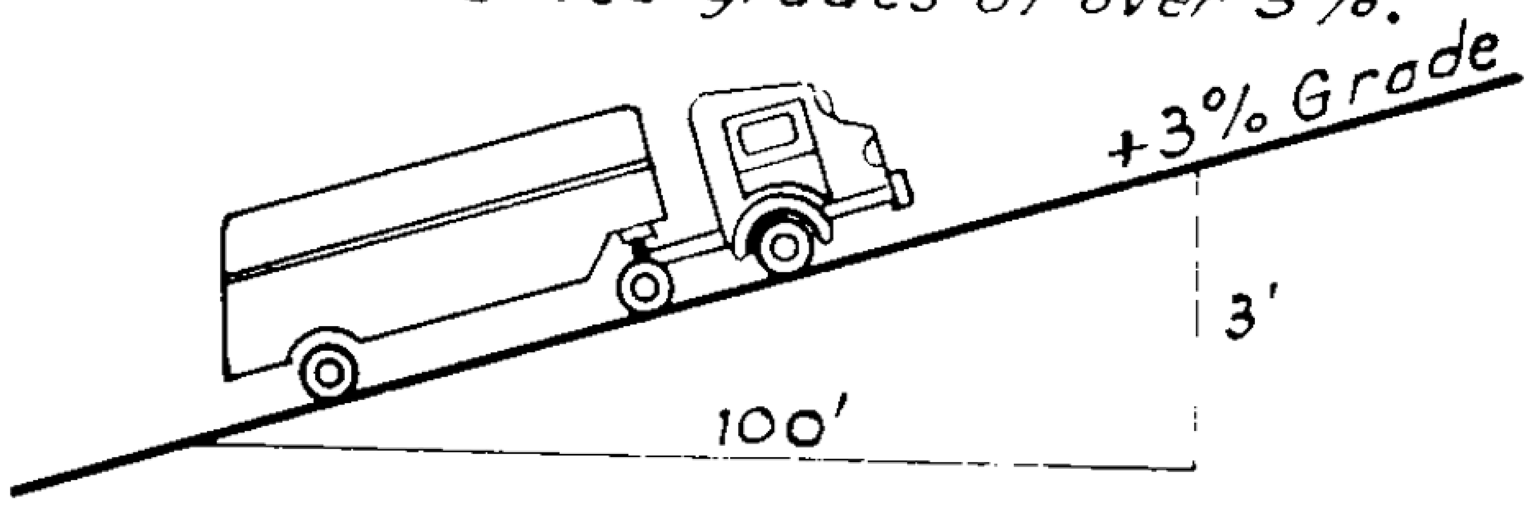
TABLE B – MINIMUM CURVE RADII – "S" NOT OVER 0.10 FOOT PER FOOT *

	DESIGN SPEED – MILES PER HOUR 30	40	50	60	70	80	90	100
MIN. SAFE RADIUS "R"	232'	412'	644'	928'	1,368'	1,949'	2,714'	3,722'
MAX. DEG. OF CURVE "D"	24.9	13.9	8.9	6.2	4.2	2.9	2.1	1.5

* Adapted from Transition Curves for Highways by Joseph Barnett, P.R.A. and Concrete Pavement Manual, Portland Cement Association.

ROADS – GRADIENTS

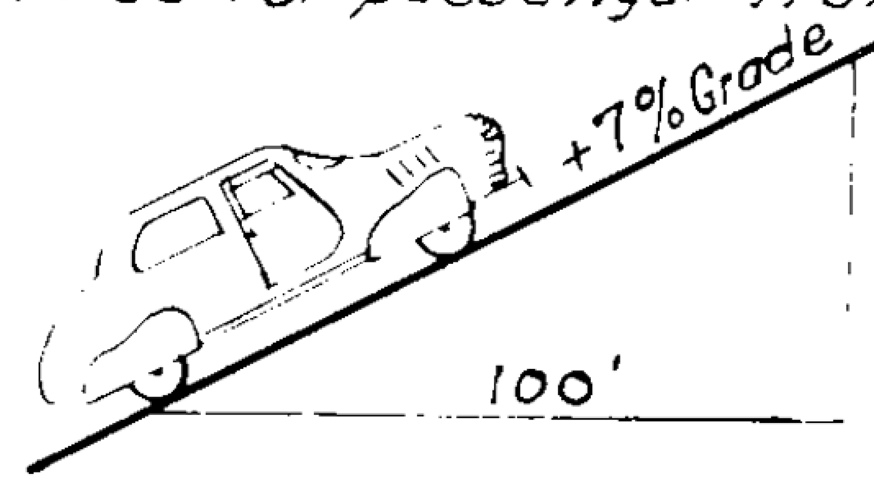
Either speed or pay load must be drastically reduced on sustained grades of over 3%.



COMMERCIAL VEHICLES.

Heavy trucks can normally operate in high gear on maximum sustained grades up to 3%. Passing facilities (added lanes or long sight distance) should be provided on mixed traffic roads where grades can not be reduced to 3%.

Reduction of grades of less than 5% or 6% is not warranted for passenger traffic only.

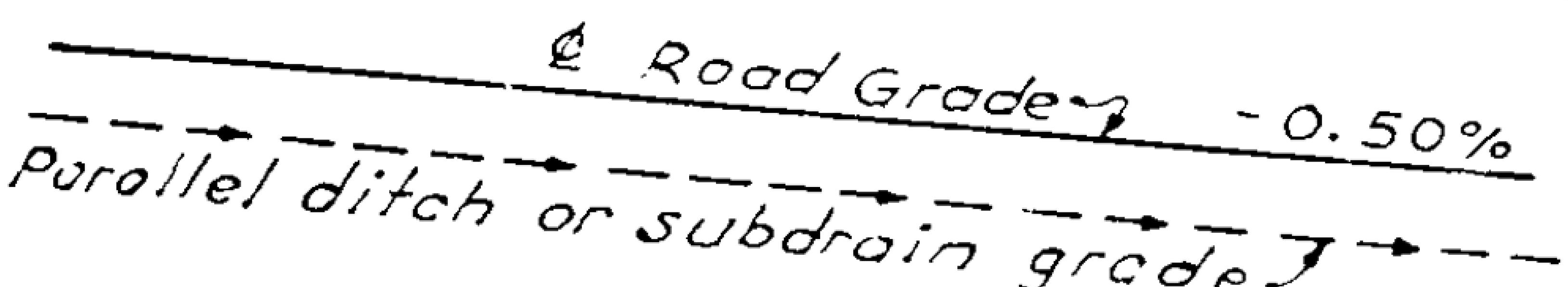


PASSENGER VEHICLES.

Automobiles can normally operate in high gear on maximum sustained grades up to 7%. Reduction of sustained grades to 5% or 6% for automobile traffic is justified, however, by the need for safety.

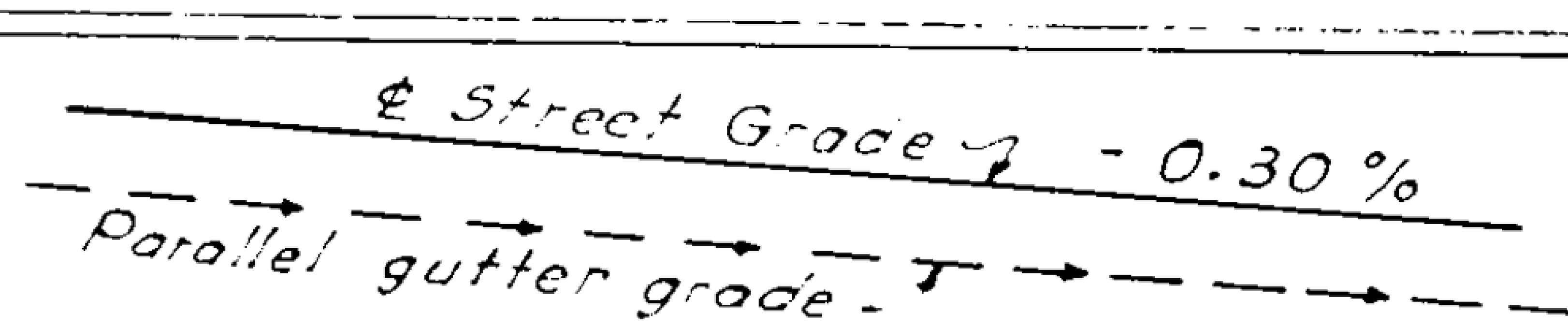
6% is the maximum sustained grade for safe operation of trucks and automobiles. On mountain roads, in high altitudes and areas subject to frequent ice, snow, sleet and fog the maximum safe sustained grade is about 5% for all vehicles.

FIG. A – MAXIMUM SUSTAINED GRADES.*



The minimum grade for good ditch drainage is 0.50%. 1% is preferable and 0.25% is the absolute minimum.

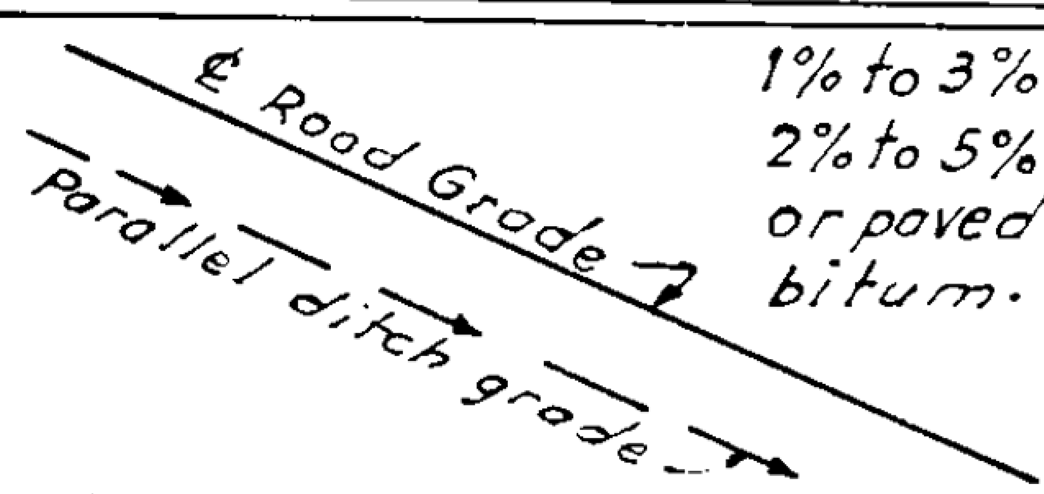
ROADS



The minimum grade for good gutter drainage is 0.30%. With great care in construction an absolute minimum of 0.10% may be used.

STREETS

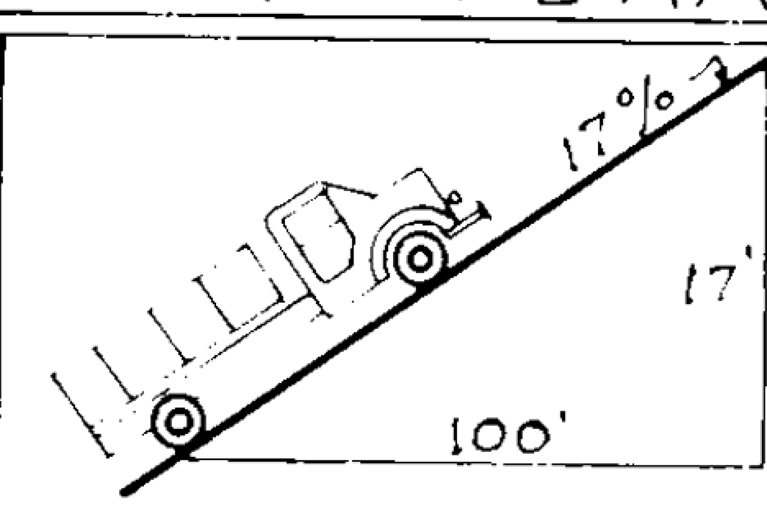
FIG. B – MINIMUM GRADES FOR DRAINAGE.**



1% to 3% - Sodded ditches.
2% to 5% - Ditch checks, sod or paved ditch of concrete, bitum. or rubble.

Silty soils will erode on grades over 1%
Most soils will erode on grades over 2%
See Table A-Pg. 5-09 for data on velocities.

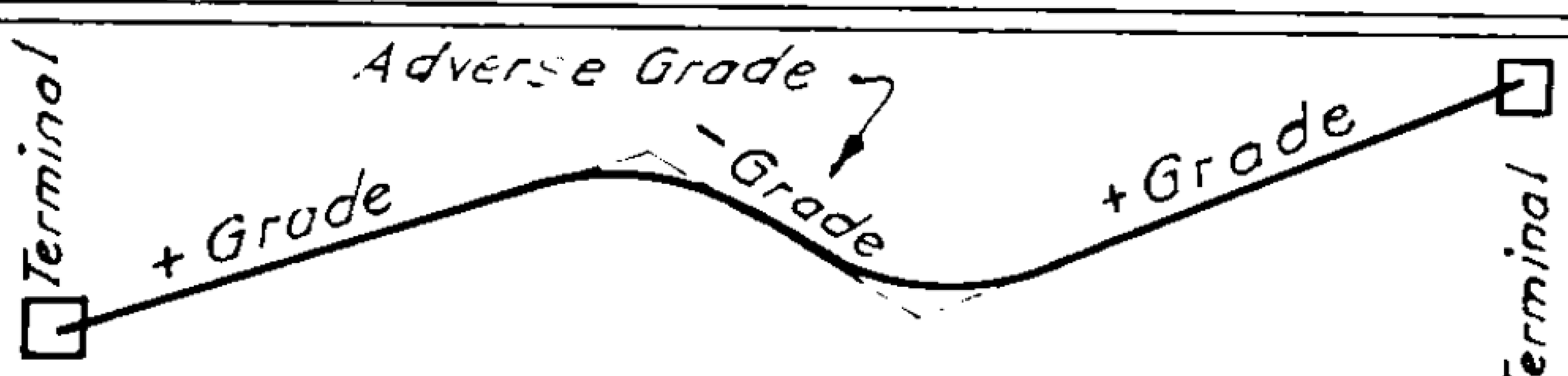
FIG. C – MAXIMUM DITCH GRADES.



The steepest grades on existing paved highways or streets in the U.S.A are 9% to 12% for highways and 30% to 32% for urban streets.

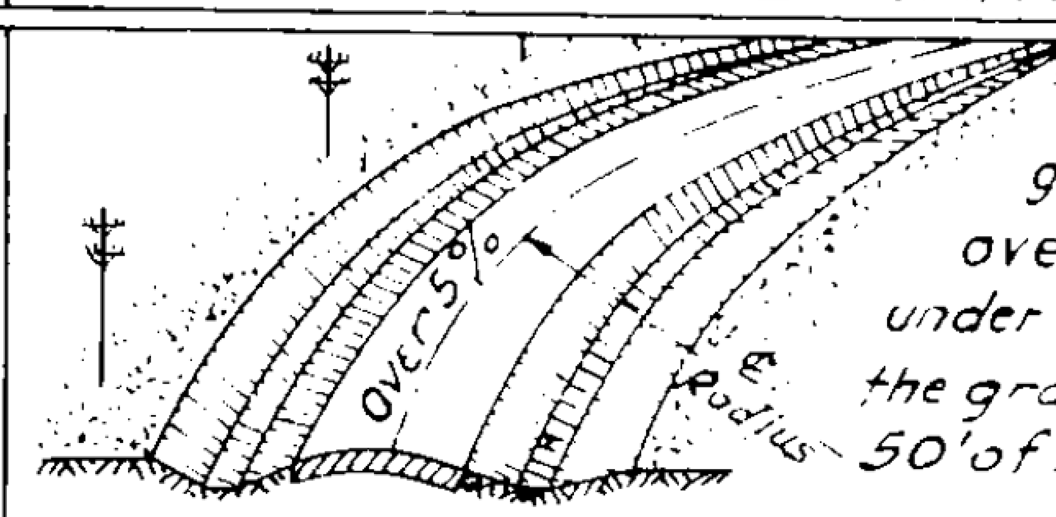
The average commercial vehicle can ascend a continuous 17% grade in low gear: use only for ramps, access, driveways.

FIG. D – ABSOLUTE MAXIMUM GRADE.



A grade which is contrary to the general rise or fall between terminals is an adverse grade and should be avoided when practicable because of wasted energy.

FIG. E – ADVERSE GRADES.



Compensate the grade if grade is over 5% on curves under 500' Rad. by reducing the grade 0.5% for each 50' of rad. less than 500'.

(Combined maximum curve and grade should be avoided if at all practicable)

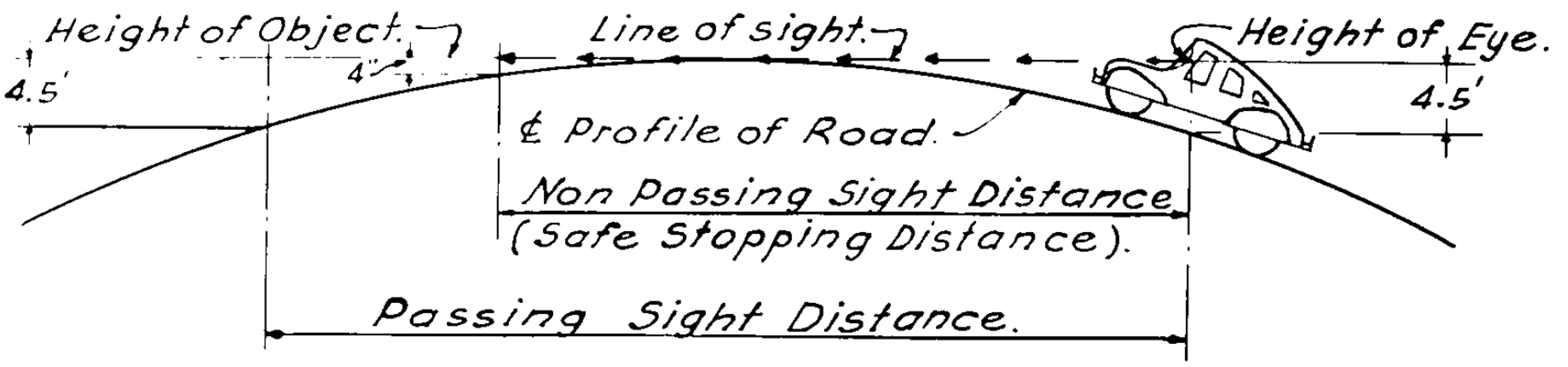
FIG. F – GRADE COMPENSATION.

TABLE G – LIST OF PHYSICAL GRADE CONTROL POINTS.

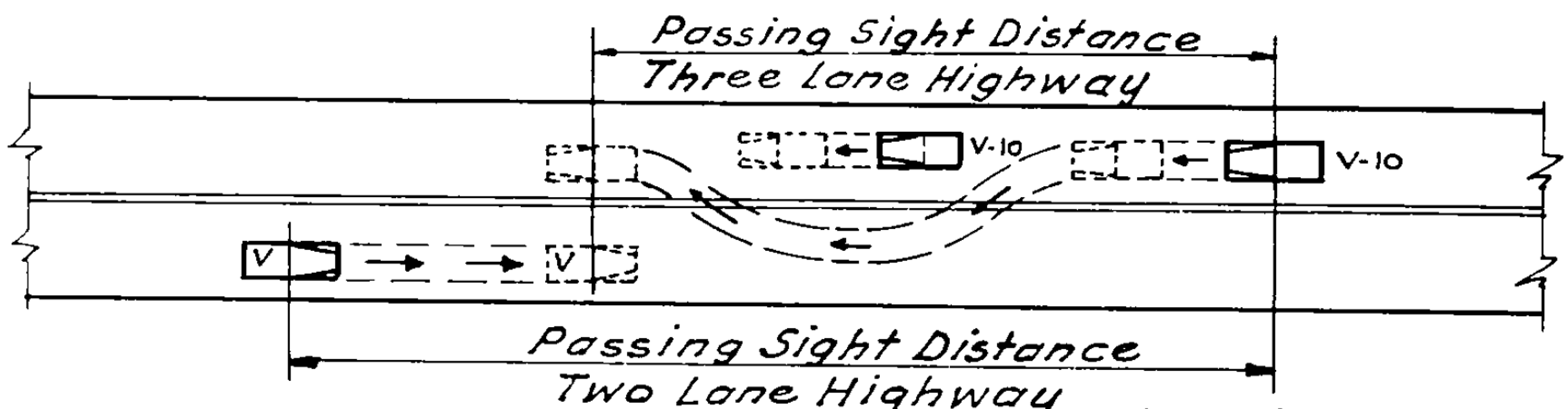
1. Elevation of existing & proposed intersecting roads, streets, bridges, separations & railroad tracks.	6. Elevation of ground water table.
2. High water at streams, swamps & lowlying areas.	7. Unstable soil strata & rock or ledge elevation.
3. Access to adjacent buildings & properties.	8. Cut and fill balance; do not sacrifice design criteria to balance quantities.
4. Maximum gradient for type of traffic expected.	9. Adequate cover over culverts.
5. Sight distance at sags, summits & intersections.	10. Minimum & Max. grades for drainage & erosion.
	11. Snow drifting areas & late melting location.

* Reference: Public Roads, Vol. 23, No. 3, and Bulletin 65, Iowa Experiment Station, Ames, Iowa.
** Reference: Concrete Pavement Manual, Portland Cement Assoc.

ROADS — SIGHT DISTANCE-1



PROFILE

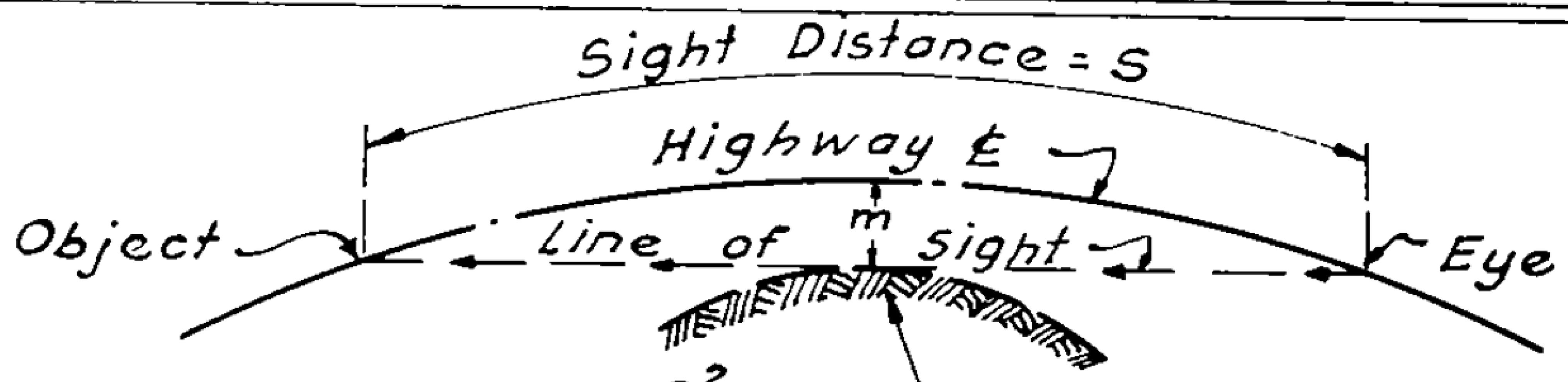


V = Design Speed.
V-10 = Design Speed minus 10 m.p.h.

PLAN

FIG. A-VERTICAL SIGHT DISTANCES. †

On three lane highways opposing traffic should be restricted from using center lane in passing zones by pavement markings.



Radius of curve required = $\frac{S^2}{8m}$
S = Sight Distance
m = Distance from ℄ to obstruction.

Location of obstruction or slope in cut, 4.5' above ℄ grade.

PLAN VIEW

FIG. B-HORIZONTAL SIGHT DISTANCE.

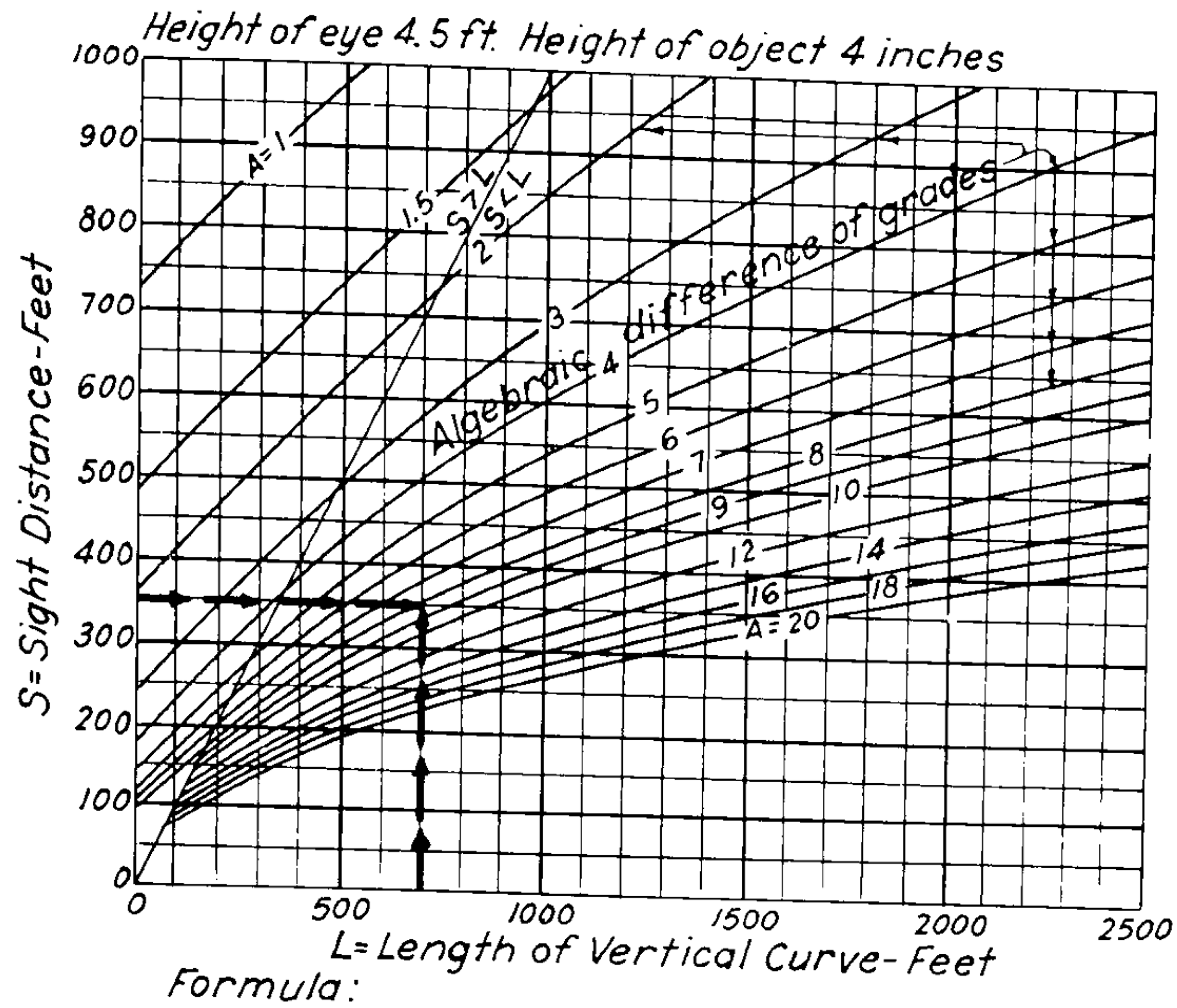
TABLE C – MINIMUM VERTICAL & HORIZONTAL SIGHT DISTANCES. †

DESIGNED SPEED	PASSING - PROVIDE AS OFTEN AS PRACTICABLE				NON - PASSING
	TWO - LANE HIGHWAY		THREE - LANE HIGHWAY		PROVIDE AT ALL POINTS ON ALL HIGHWAYS
	DESIRABLE	ABSOLUTE	DESIRABLE	ABSOLUTE	
30 m.p.h.	600 Feet	500 Feet			200 Feet
40 m.p.h.	1100 Feet	900 Feet			275 Feet
50 m.p.h.	1600 Feet	1400 Feet	1100 Feet	900 Feet	350 Feet
60 m.p.h.	2300 Feet	2100 Feet	1500 Feet	1300 Feet	475 Feet
70 m.p.h.	3200 Feet	2900 Feet	2000 Feet	1800 Feet	600 Feet
80 m.p.h. *					750 Feet
90 m.p.h. *					950 Feet
100 m.p.h. *					1200 Feet

* Concrete Pavement Manual - P.C.A.

† Adapted from A Policy on Sight Distance for Highways, A.A.S.H.O.

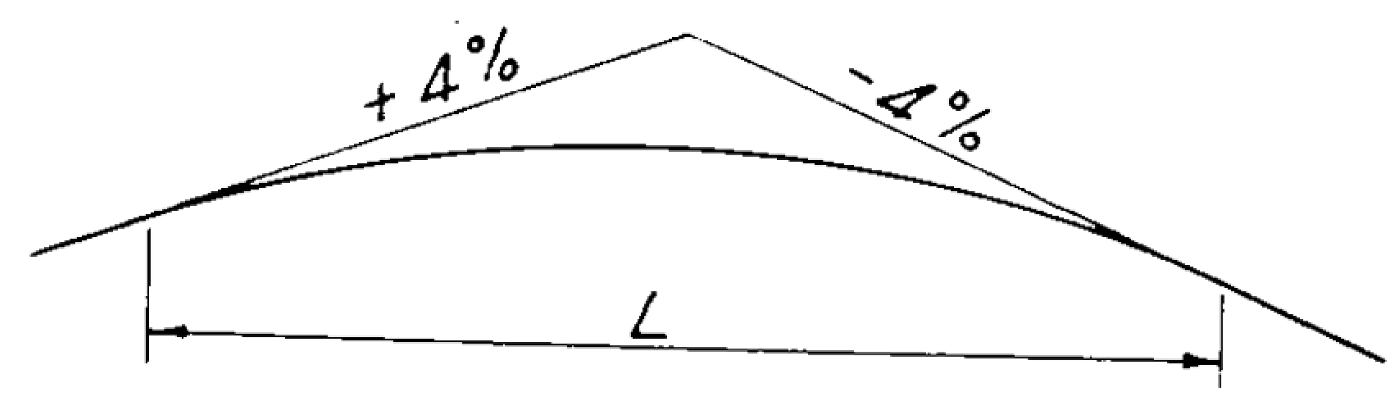
ROADS — SIGHT DISTANCE - 2



Formula:

When S>L $S=\frac{7.28}{A}+\frac{L}{2}$ When S<L $S=3.82\sqrt{\frac{L}{A}}$ A = algebraic diff. of grades ÷ 100.

Example



Given:

Design speed (assume 50 m.p.h.).
% of intersecting grades.

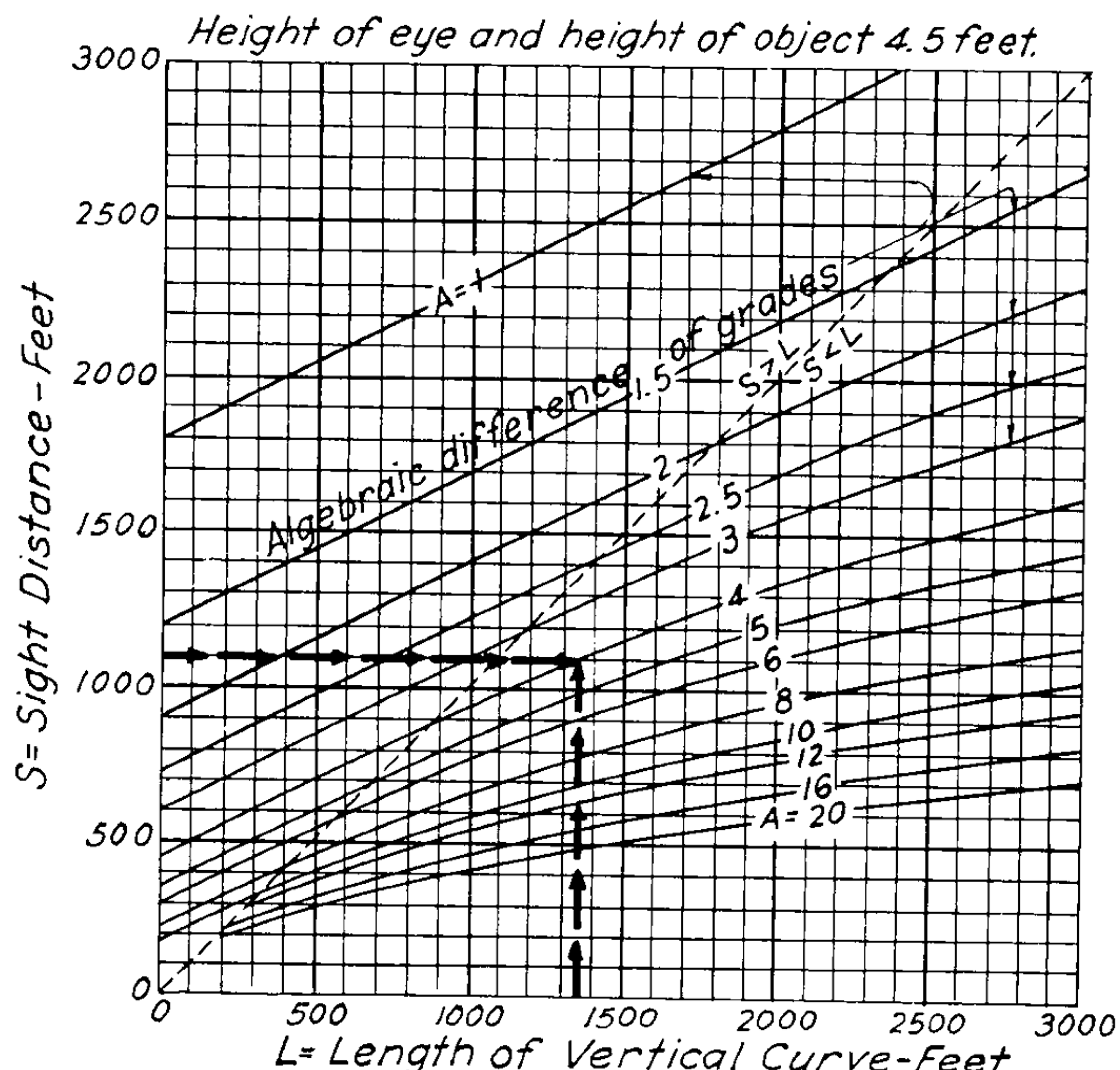
Required:

Length of vertical curve for non-passing sight distance.

Solution:

Non-passing sight distance from table on Page 3-60 = 350 ft.
Algebraic diff. = +4-(-4) = 8
Determine L from chart = 700 ft.

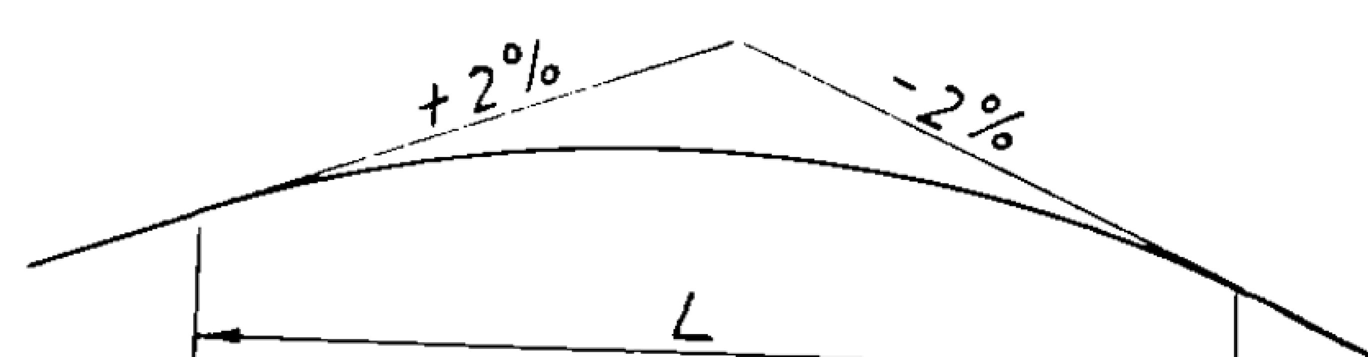
FIG. A - NON-PASSING SIGHT DISTANCE CHART.*



Formula:

When S>L $S=\frac{18}{A}+\frac{L}{2}$ When S<L $S=6\sqrt{\frac{L}{A}}$ A = Algebraic diff. of grades ÷ 100.

Example



Given:

Design speed (assume 40 m.p.h.).
% of intersecting grades.
Type of road (assume two-lane).

Required:

Length of vertical curve for passing sight distance.

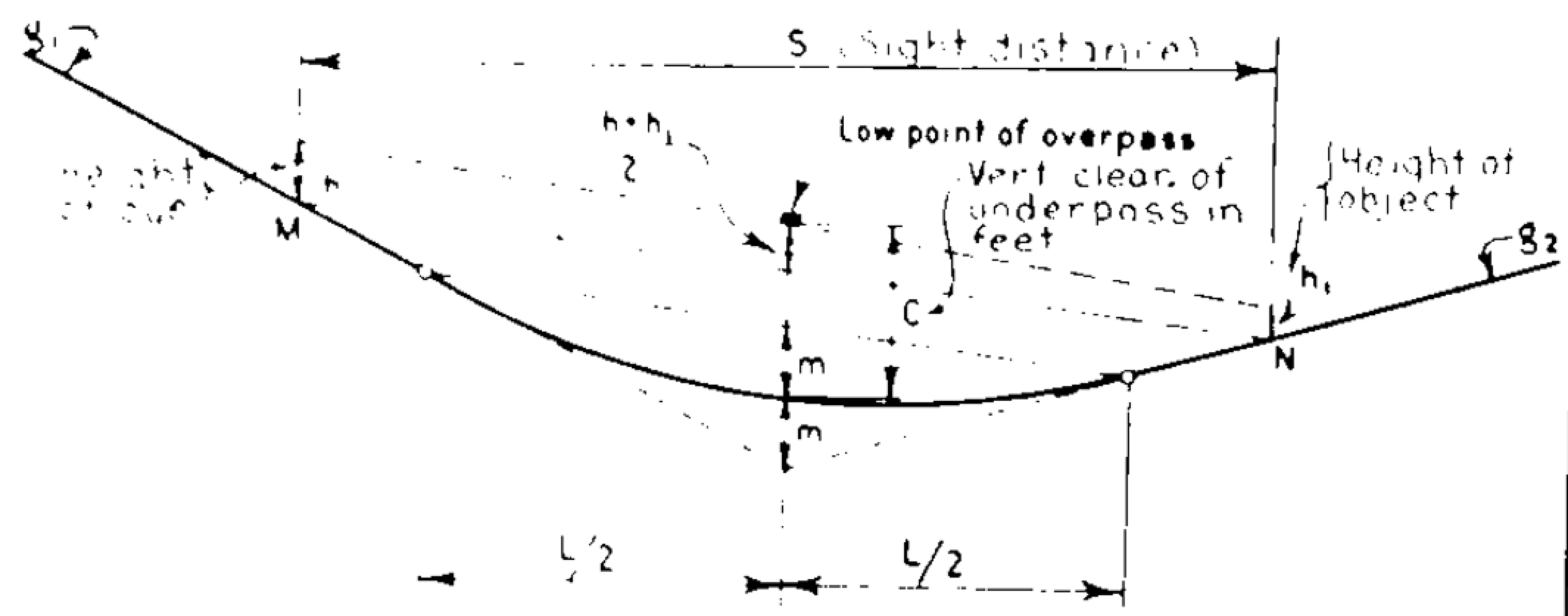
Solution:

Passing sight distance from Table C, Page 3-60 = 1100 feet.
Algebraic diff. = +2-(-2) = 4
Determine L from chart = 1350 ft.

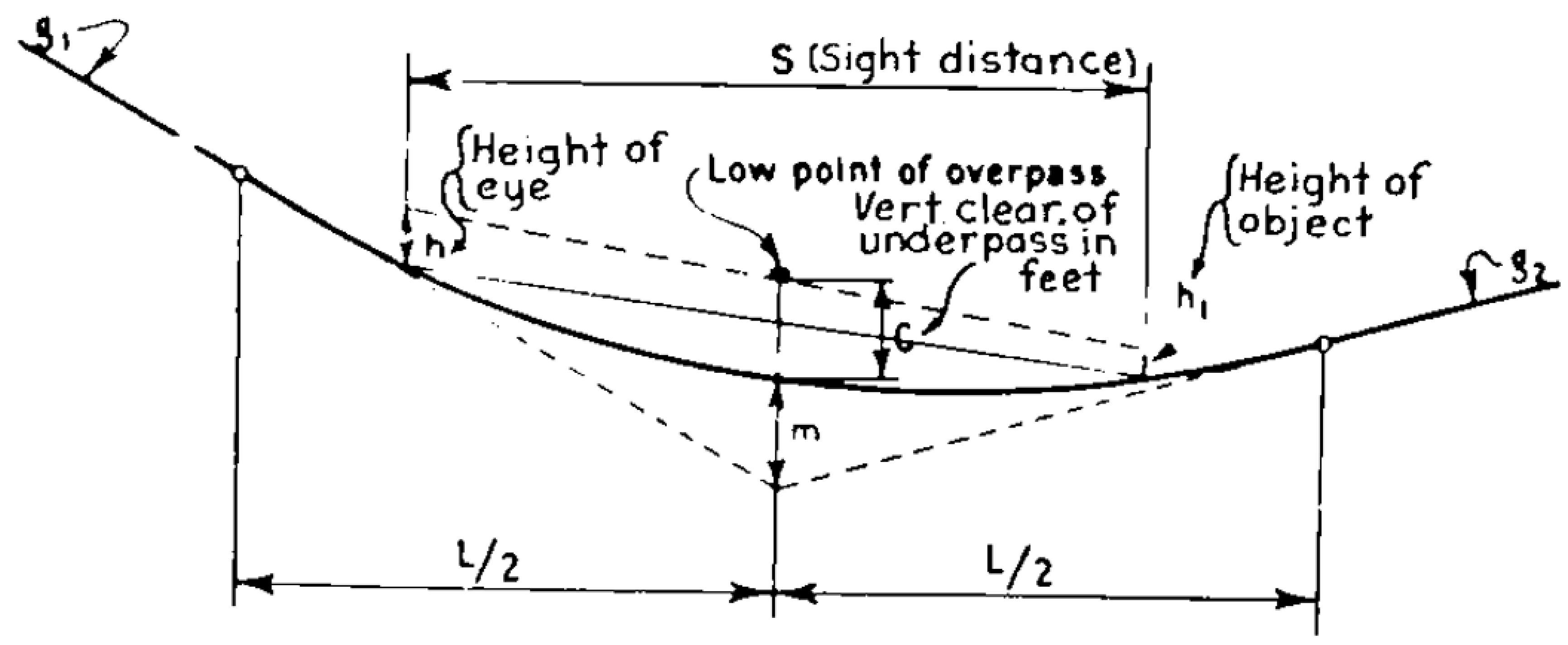
FIG. B - PASSING SIGHT DISTANCE CHART.*

*Adapted from A Policy on Sight Distance for Highways, A.A.S.H.O.

ROADS — SIGHT DISTANCE - 3



CASE I ~ SIGHT DISTANCE GREATER THAN LENGTH OF VERTICAL CURVE, OR S>L



CASE II ~ SIGHT DISTANCE LESS THAN LENGTH OF VERTICAL CURVE, OR S<L

PASSING (Case I)

Formula: (Based on C=14'-6", h=4'-6", h_1=4'-6")

$L = 2S - \frac{80}{A}$ (where "S" is in 100' stations)

Example:

Given: S=6, A (algeb. diff. = 8)

Required: Length of vertical curve, "L"

Solution: $L = 12 - \frac{80}{8} = 2$ (100' sta.)

NON-PASSING (Case I)

Formula: (Based on C=14'-6", h=4'-6", h_1=6")

$L = 2S - \frac{96}{A}$

Example:

Given: S=8, A=8

Required: Length of vertical curve, "L"

Solution: $L = 16 - \frac{96}{8} = 4$ (100' sta.)

PASSING (Case II)

Formula: (Based on C=14'-6", h=4'-6", h_1=4'-6")

$L = \frac{S^2A}{80}$ (where "S" is in 100' stations)

Example:

Given: S=11, A (algeb. diff.) = 8

Required: Length of vertical curve, "L"

Solution: $L = \frac{11^2 \times 8}{80} = 12.1$ (100' sta.)

NON-PASSING (Case II)

Formula: (Based on C=14'-6", h=4'-6", h_1=6")

$L = \frac{S^2A}{96}$

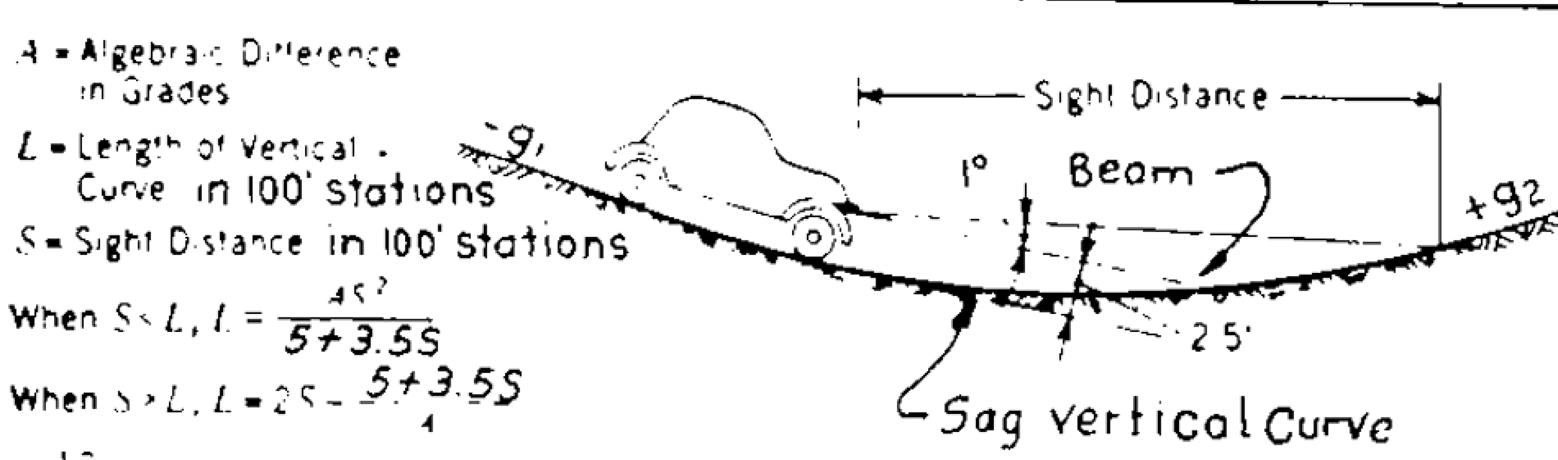
Example:

Given: S=13, A=8

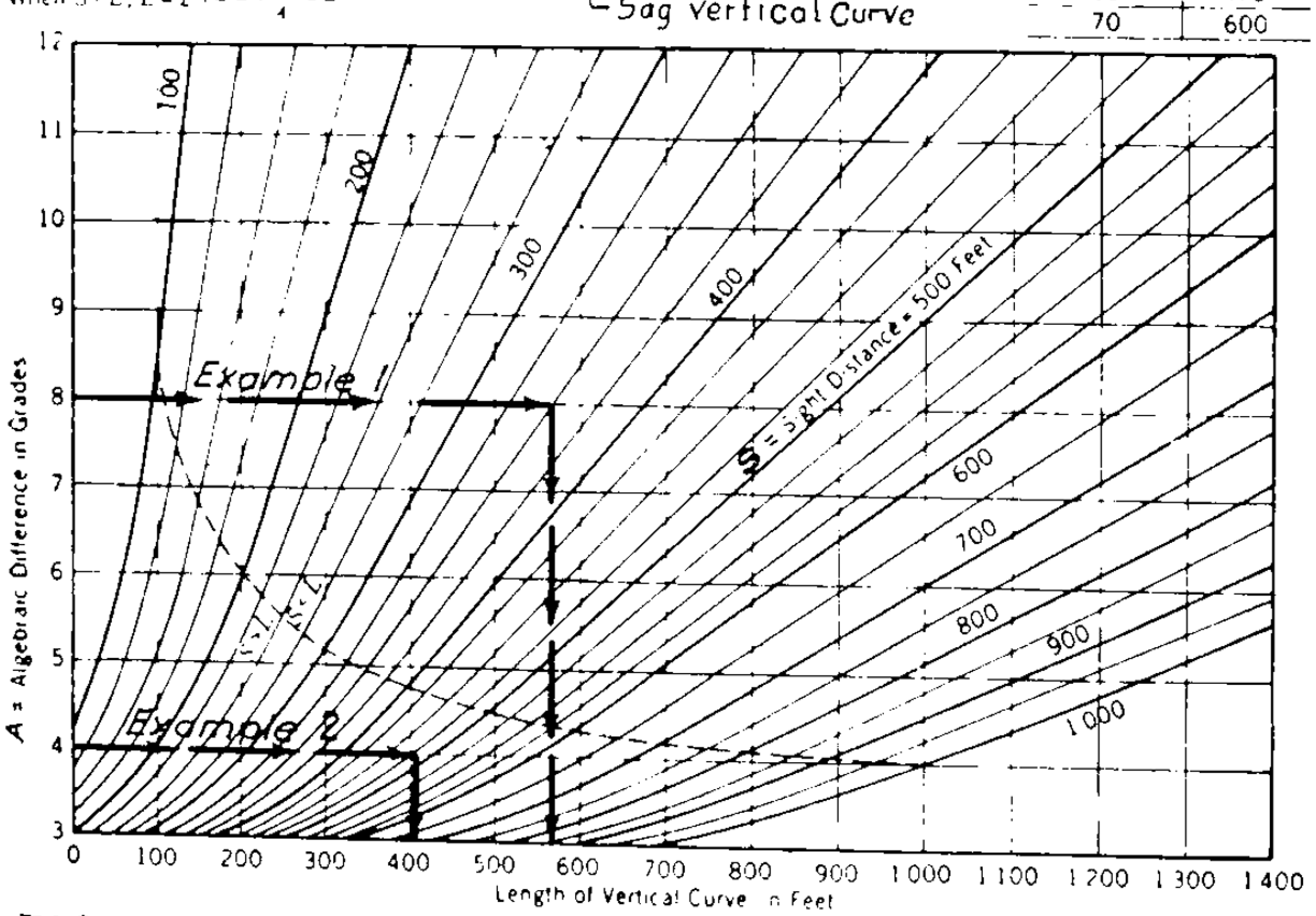
Required: Length of vertical curve, "L".

Solution: $L = \frac{13^2 \times 8}{96} = 14.08$ (100' sta.)

FIG. A - SIGHT DISTANCE AT UNDERPASS.*



Design Speed Mi. per Hr.	Sight Distance in Feet
30	200
40	275
50	350
60	475
70	600



Example 1. - S<L

Given: Design speed - 50 m.p.h. and A=8

Required: Sight distance and length of vertical curve, "L"

Solution: From table, sight distance = 350 feet and from chart, L= 568 feet.

Example 2. - S>L

Given: Design speed 60 m.p.h. and A=4

Required: Sight distance and length of vertical curve, "L"

Solution: From table, sight distance = 475 feet and from chart L=410 feet.

Based on headlight illumination for safe stopping distance.

FIG. B - HEADLIGHT SIGHT DISTANCE CHART - SAG VERTICAL CURVES.**

* Adapted from American Highway Practice by L. I. Hewes.
** Adapted from Civil Engineering, Jan. 1944 Pg. 22 - Fig. 2 by D. Thompson.

ROADS-VERTICAL CURVES (Parabolic)

Formulas

A = Algebraic difference of grades $= +g_1\% - (-g_2\%)$

$e = \frac{AL}{8}$

$d = \frac{l^2 A}{2L}$; $d = 4e\left(\frac{l}{L}\right)^2$

Example

Given:

$g_1\% = +3.00\%$; $g_2\% = -2.00\%$; $L = 3.00$; $l = 0.50$

Required:

A, e and d.

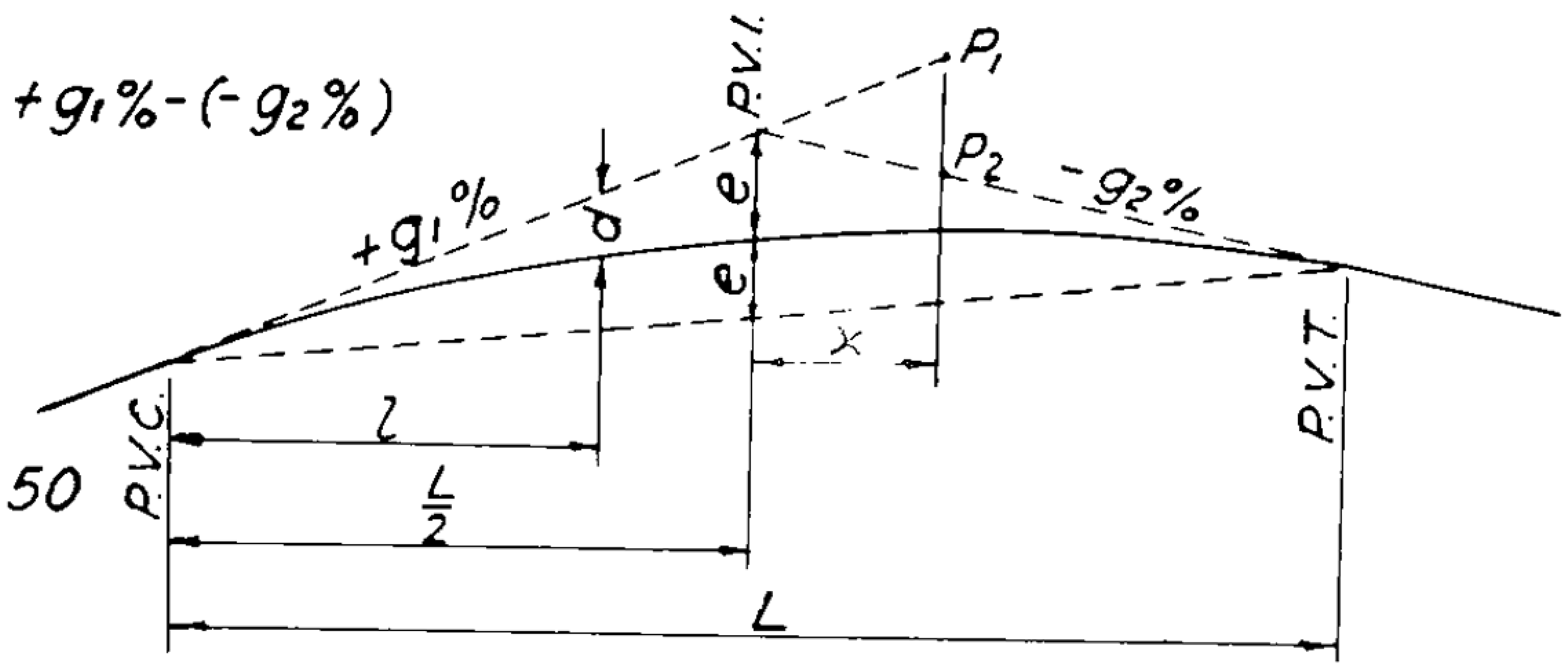
Solution:

$A = 3.00 - (-2.00) = 5.00$

$e = \frac{5.00 \times 3.00}{8} = 1.875'$

$d = \frac{0.50^2 \times 5.00}{2 \times 3.00} = 0.208'$

Also- $d = 4(1.875)\left(\frac{0.50}{3.00}\right)^2 = 0.208'$



VERTICAL SUMMIT CURVE

Length of vertical summit curves should provide required sight distance. See page 3-60.

NOTE: All horizontal distances shown on this page - L, l, l_1, l_2, x, x_1, x_2 - are expressed in 100' stations.

Where L, length of vertical curve, is not determined by sight distance criteria the minimum value for comfort is $L = \frac{AV^2}{10{,}000}$ *

TO FIND STA. OF P.V.I. WHEN ELEVATIONS OF P_1 AND P_2 ARE KNOWN.

Formula

$x = \frac{\text{elev. } P_1 - \text{elev. } P_2}{A}$

Example

Given:

Elev. $P_1 = 154.50$; Elev. $P_2 = 150.00$; $A = 5.00$

Required:

x = distance in 100' stations from known point to P.V.I.

Solution:

$x = \frac{154.50 - 150.00}{5.00} = 0.90$ (100' stations)

TO FIND LOW POINT ON SAG CURVE

Formulas

$x = g\text{(lesser gradient)}\frac{L}{A}$

$d\text{ (at low point)} = \frac{x^2 A}{2L}$

Example

Given:

$g_1\% = -3.00\%$; $g_2 = +2.00\%$; $L = 3.00$; $A = 5.00$

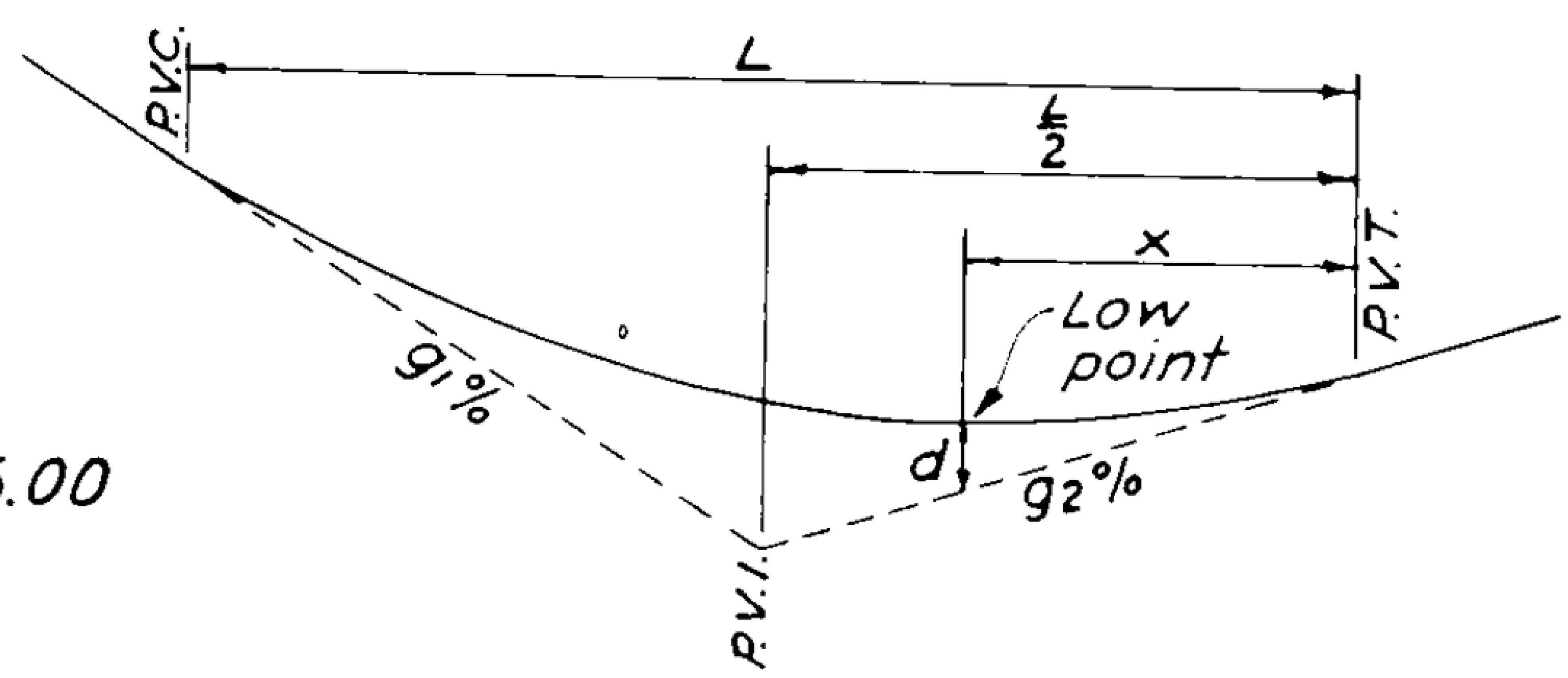
Required:

x and d

Solution:

$x = 2.00 \times \frac{3.00}{5.00} = 1.20$

$d = \frac{1.20^2 \times 5.00}{2 \times 3.00} = 1.20'$



VERTICAL SAG CURVE

Length of vertical sag curve should provide headlight illumination for a safe stopping distance. See page 3-62.

NOTE: High point on summit curve can be found by same method.

FIG. A - SYMMETRICAL VERTICAL CURVES.

Formulas

$e = \frac{l_1 l_2}{2(l_1 + l_2)}(A)$; $y_1 = e\left(\frac{x_1}{l_1}\right)^2$; $y_2 = e\left(\frac{x_2}{l_2}\right)^2$

Example

Given:

$g_1 = 3.00\%$; $g_2 = 2.00\%$; $L = 4.00$; $l_1 = 1.50$; $l_2 = 2.50$; $x_1 = 0.50$; $x_2 = 1.00$

Required:

e, y_1 and y_2

Solution:

$e = \frac{1.50 \times 2.50}{2(1.50 + 2.50)}(3.00 + 2.00) = 2.35'$

$y_1 = 2.35\left(\frac{0.50}{1.50}\right)^2 = 0.26'$

$y_2 = 2.35\left(\frac{1.00}{2.50}\right)^2 = 0.38'$

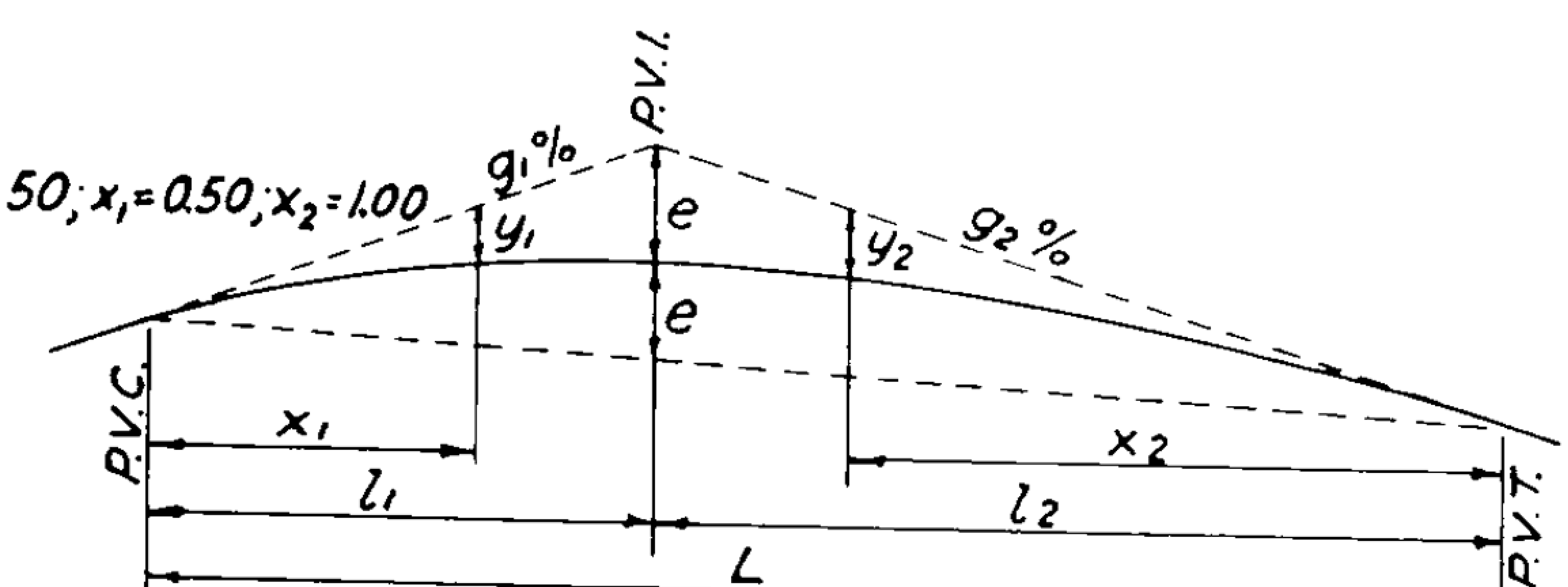


FIG. B - UNSYMMETRICAL VERTICAL CURVES.

Used to fit unusual conditions

* From O'Rourke, General Engineering Handbook, Mc Graw-Hill.

ROADS - MOTOR VEHICLE DATA

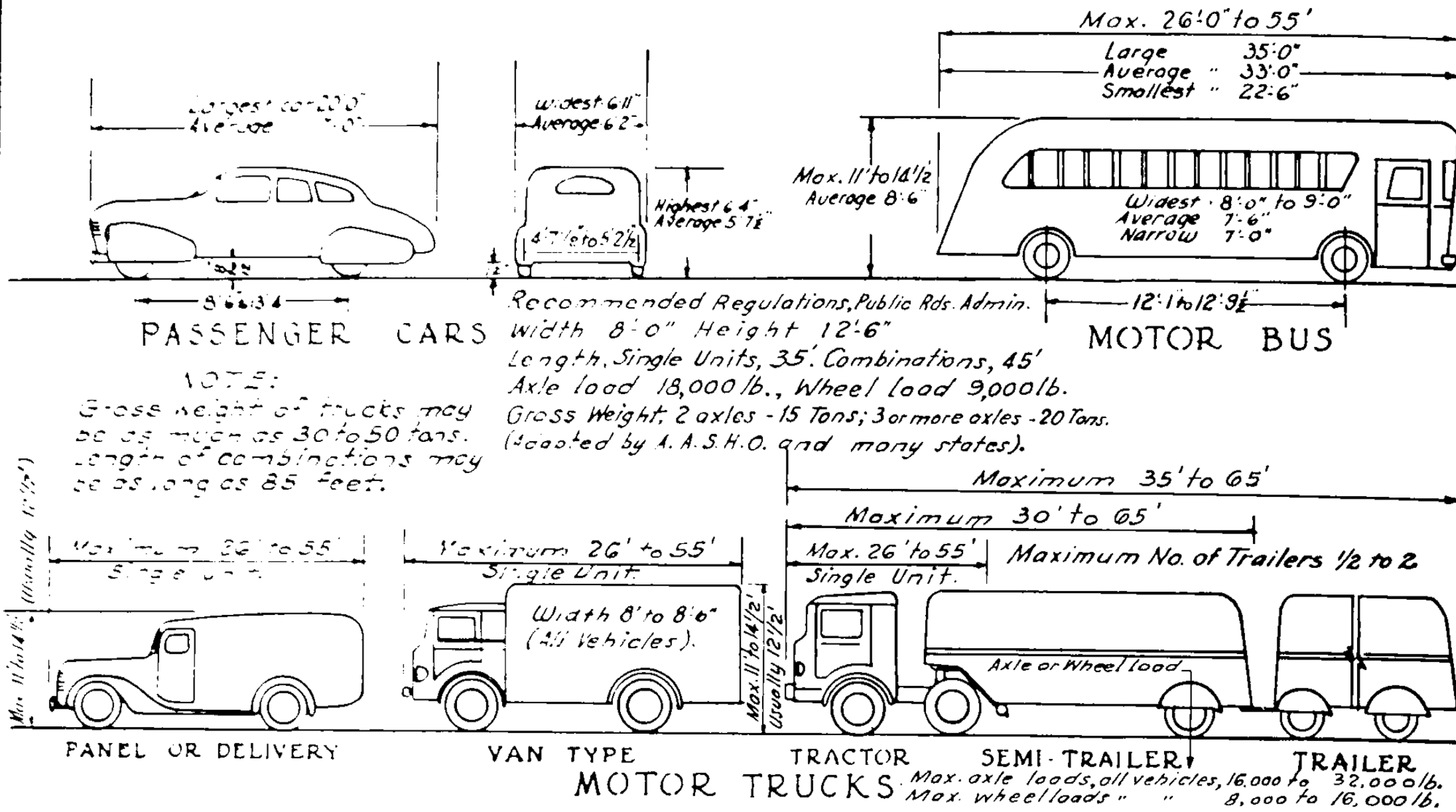


FIG. A - DIMENSIONS OF MOTOR VEHICLES.*

For individual state restrictions on motor vehicles, consult Natl. Highway Users Confer., Washington, D.C.

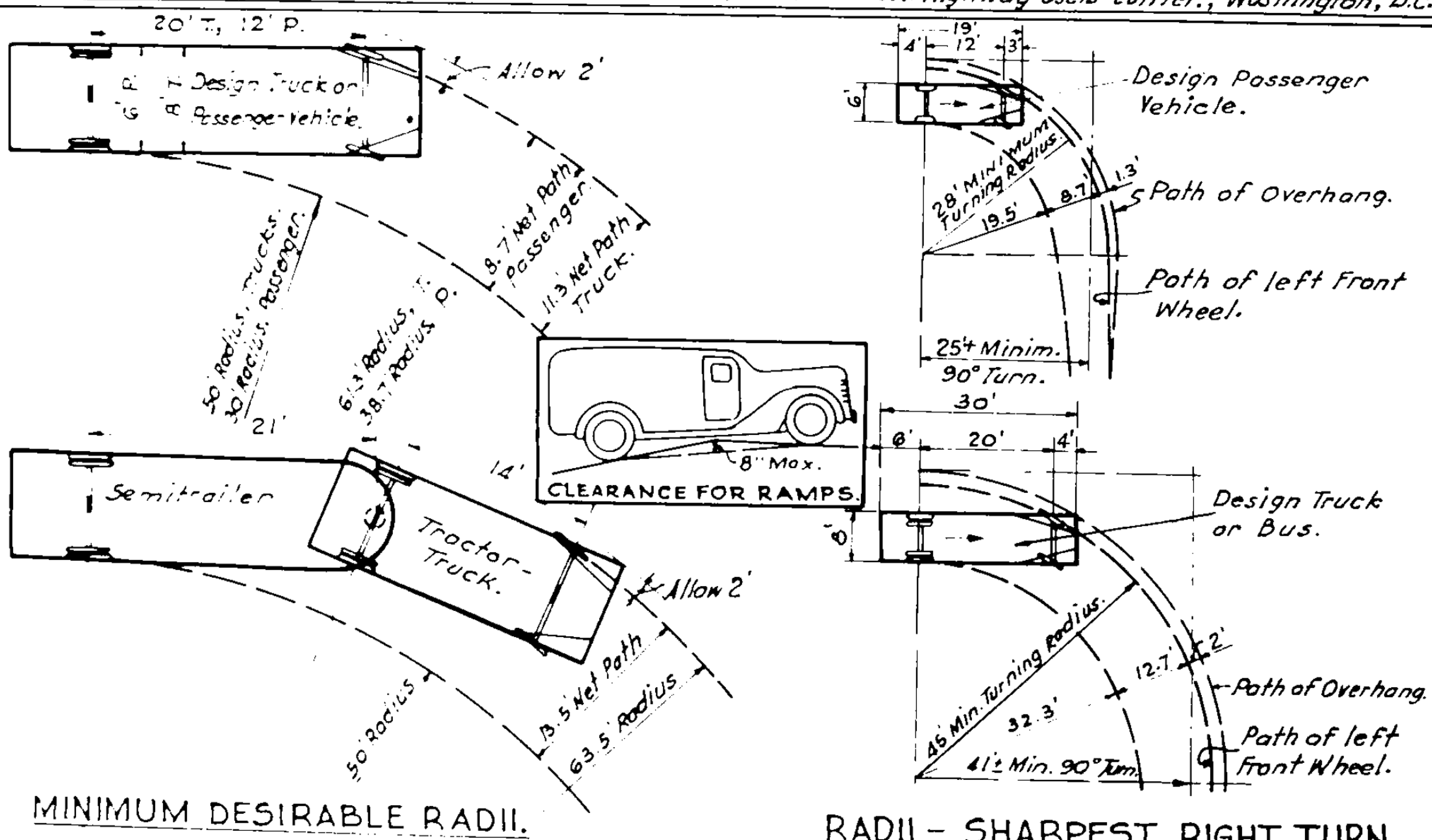


FIG. B - TURNING RADII FOR MOTOR VEHICLES.**

* Adopted from Architectural Graphic Standards by Ramsey & Sleeper.
** Adapted from A Policy on Intersections at Grade by Amer. Assoc. State Highway officials.

ROADS - INTERSECTIONS AT GRADE *

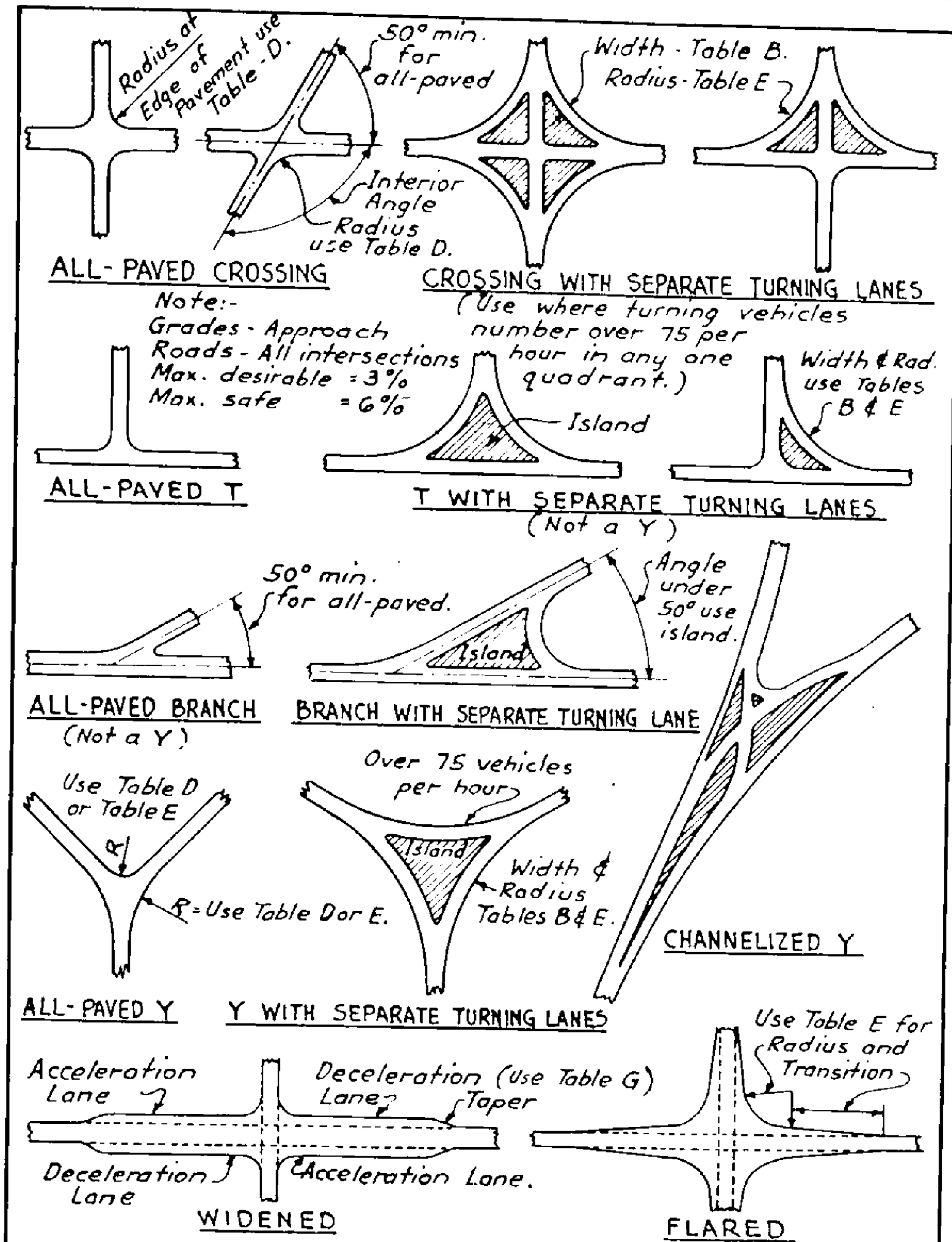


FIG. A - TYPES OF INTERSECTIONS AT GRADE.

TABLE B - PAVEMENT WIDTHS FOR SEPARATE TURNING LANES.

RADIUS	TURNING SPEED	PAVEMENT WIDTH FOR TYPE OF TRAFFIC: 1-WAY 1-LANE ✝✝ PASSENGER	1-WAY 1-LANE ✝✝ TRUCK	1-WAY 2-LANE PASSENGER	1-WAY 2-LANE TRUCK	2-WAY 2-LANE PASSENGER	2-WAY 2-LANE TRUCK
FEET	M.P.H.	FEET	FEET	FEET	FEET	FEET	FEET
50	20	14	17	19	28	26	32
100	27	13	14	17	24	25	27
150	32	13	14	16	22	24	26
200	37	13	14	16	22	24	26
300	43	12	14	16	21	24	26
400	47	12	14	15	20	24	26
500	51	12	14	15	20	23	26

✝✝ Channelize to prevent entrance of opposing traffic.

TABLE C - TREATMENTS RECOMMENDED FOR INTERSECTIONS AT GRADE

INTERSECTING ROADS	TRAFFIC DENSITY IN VEHICLES PER HOUR				
Road A	50-100	100-300	100-300	Over 300	Over 300
Road B	50-100	Under 100	100-300	under 100	100-300
Min. All-Paved	✓	✓		✓	
Flared	✓	✓	✓	✓	✓
Channelized		Optional	✓	Optional	✓

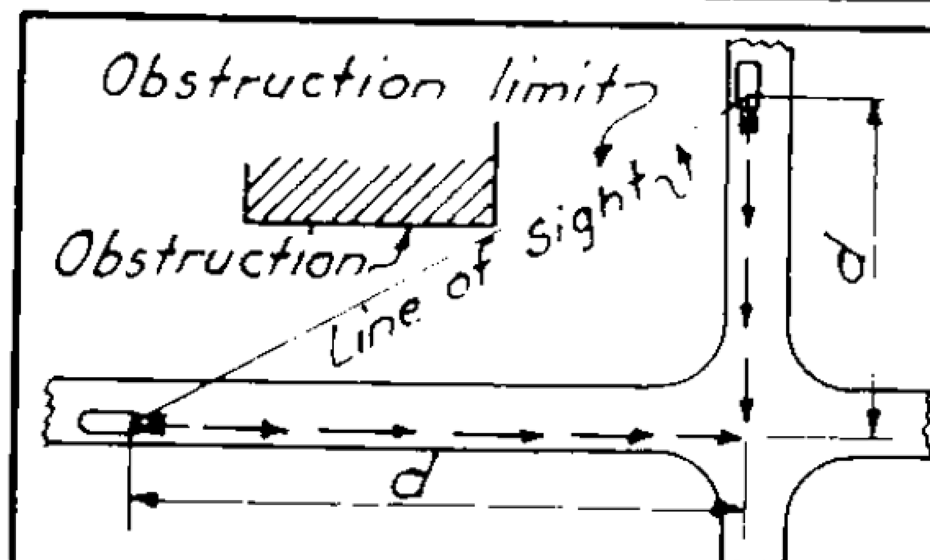
TABLE D - MINIMUM RADIUS OF EDGE ✝ OF PAVEMENT FOR LOW TURNING SPEED - 20± M.P.H.

INTERIOR ANGLE	RADIUS, "P" (PASSENGER) TRAFFIC	RADIUS, "T" (TRUCK) TRAFFIC
90°	30 Feet	50 Feet
105°	35	60
120°	45	70
135°	60	90
150°	120	150

TABLE E - MINIMUM RADIUS (MAX. DEG.) OF EDGE ✝ OF PAVEMENT FOR VARIOUS TURNING SPEEDS.

HIGHWAY DESIGN SPEED	30 M.P.H.	40 M.P.H.	50 M.P.H.	60 M.P.H.	70 M.P.H.
Turning Speed	20	30	35	40	50
Min. Radius	50'	130'	180'	250'	500'
Curve Degrees		45°	32°	23°	11°
Superelevation Feet per foot		0.05'	0.08'	0.10'	0.10'
Transition		100'	150'	200'	250'

✝ Inner edge of pavement. (Allow 2' extra for curbs.)
Use Table D for all-paved intersections.
Use Table E for separate turning lanes.



"d" is based on safe stopping distance from point of perception to intersection.

TABLE F - SIGHT DISTANCE "d" REQUIRED.

HIGHWAY DESIGN SPEED	30	40	50	60	70
"d" Rural light traffic	130'	180'	220'	260'	310'
"d" All other roads	160'	250'	360'	480'	610'

TABLE G - LENGTH OF DECELERATION AND ACCELERATION LANES.

SAFE SPEED TO MAKE TURN IN M.P.H.		HIGHWAY DESIGN SPEED M.P.H. 40	50	60	70
Acceleration Lane	30	0'	170'	500'	950'
	20	180'	400'	750'	1,200'
Deceleration Lane	30	0'	160'	240'	320'
	20	140'	220'	300'	380'
Length of Taper	Acceleration	175'	200'	250'	300'
	Deceleration	125'	150'	175'	200'

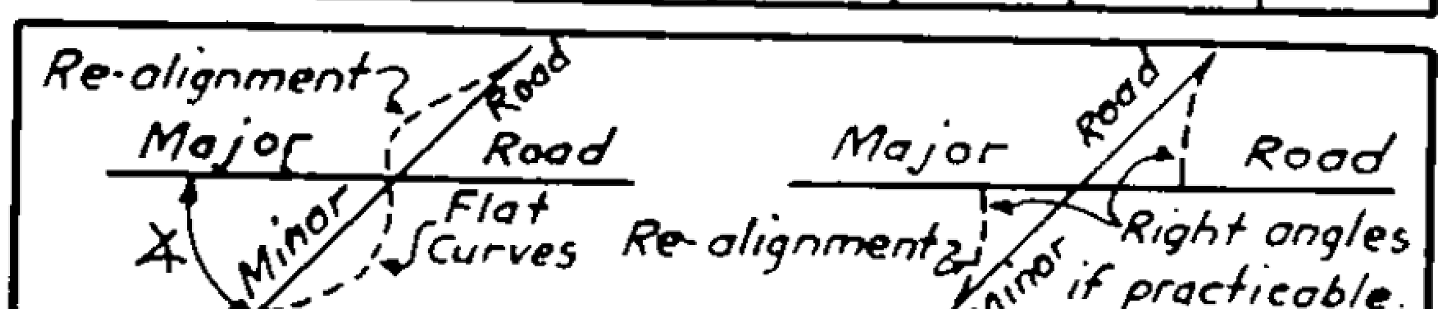


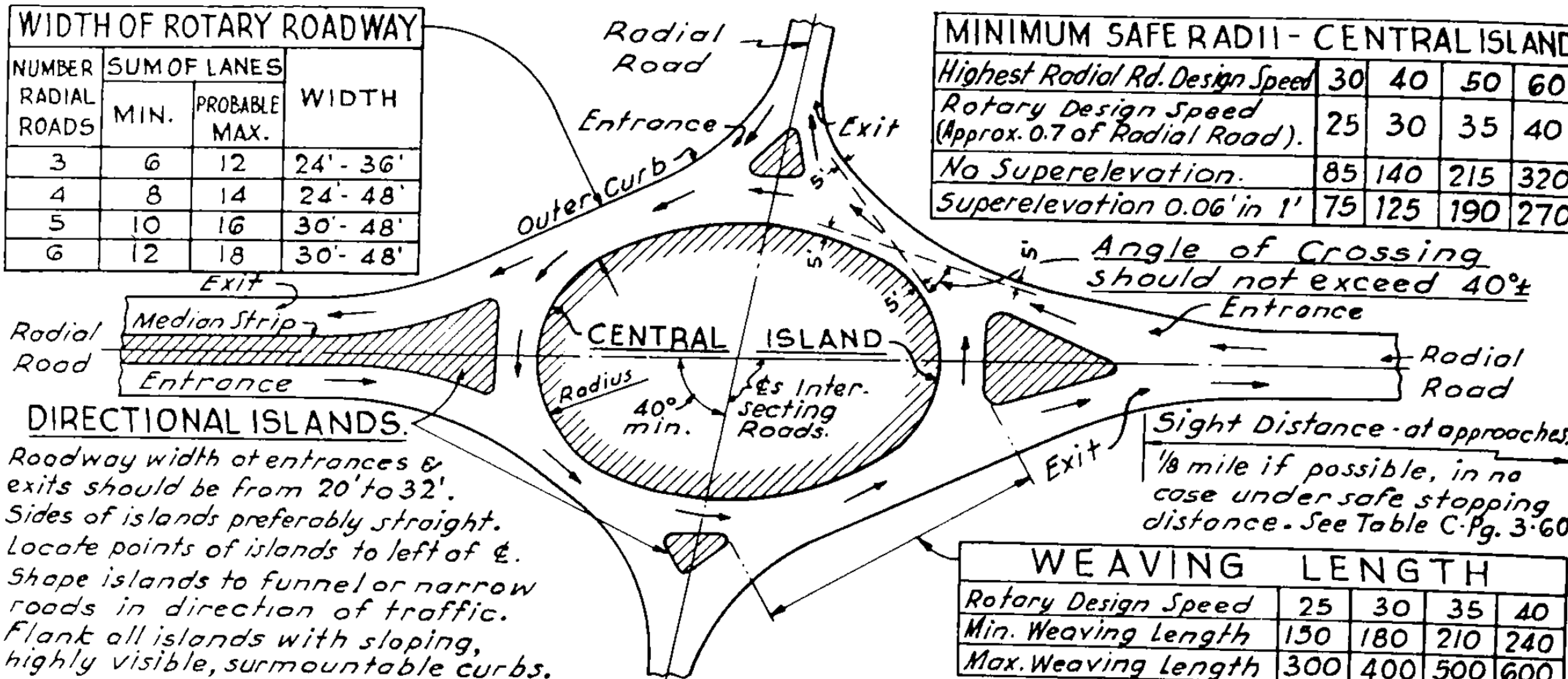
FIG. H - ALIGNMENT. If possible, roads should be designed or located to intersect at angles between 60° and 120°. Use easy, flat curves.

* From A Policy on Intersections at Grade, Amer. Assoc. of State Highway Officials (A.A.S.H.O.), Wash., D.C.

ROADS - ROTARY INTERSECTIONS

WIDTH OF ROTARY ROADWAY			
NUMBER RADIAL ROADS	SUM OF LANES MIN.	SUM OF LANES PROBABLE MAX.	WIDTH
3	6	12	24'-36'
4	8	14	24'-48'
5	10	16	30'-48'
6	12	18	30'-48'

MINIMUM SAFE RADII - CENTRAL ISLAND				
Highest Radial Rd. Design Speed	30	40	50	60
Rotary Design Speed (Approx. 0.7 of Radial Road).	25	30	35	40
No Superelevation.	85	140	215	320
Superelevation 0.06' in 1'	75	125	190	270

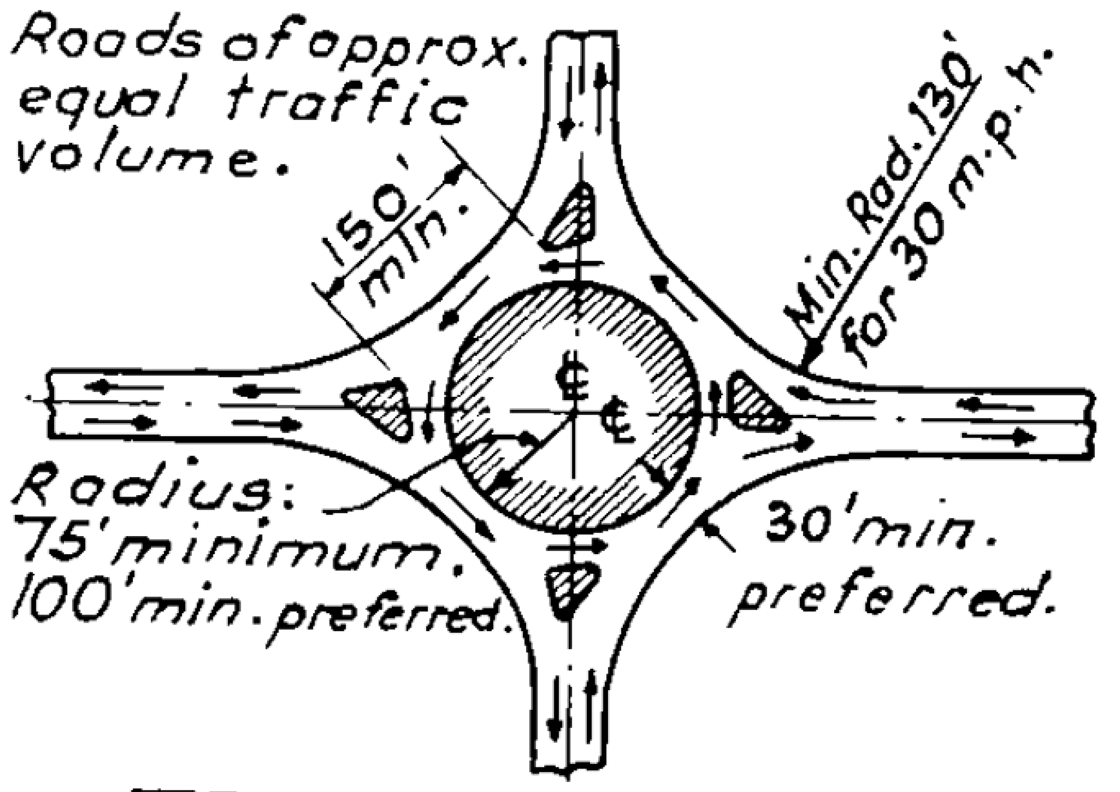


DIRECTIONAL ISLANDS.
Roadway width at entrances & exits should be from 20' to 32'.
Sides of islands preferably straight.
Locate points of islands to left of ¢.
Shape islands to funnel or narrow roads in direction of traffic.
Flank all islands with sloping, highly visible, surmountable curbs.

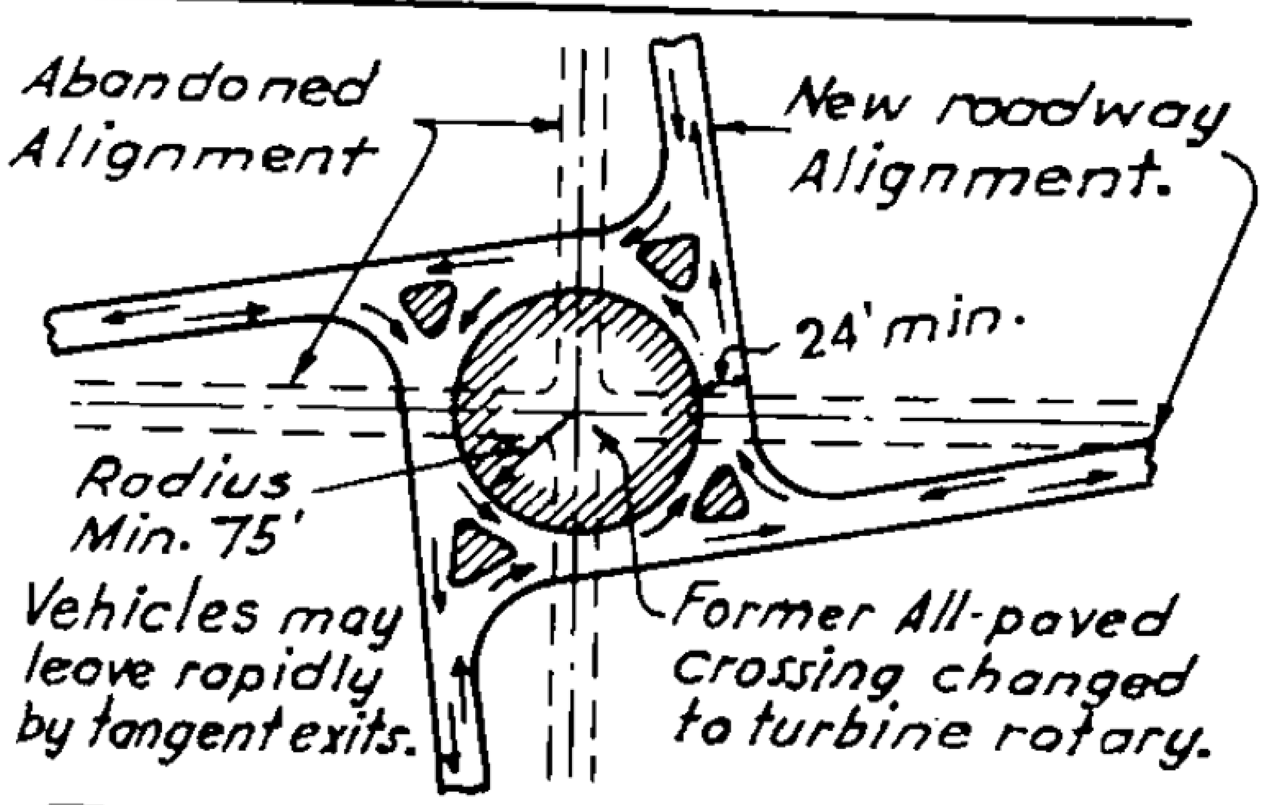
WEAVING LENGTH				
Rotary Design Speed	25	30	35	40
Min. Weaving Length	150	180	210	240
Max. Weaving Length	300	400	500	600

FIG. A - PLAN ROTARY INTERSECTION. (ILLUSTRATING DESIGN ELEMENTS) *

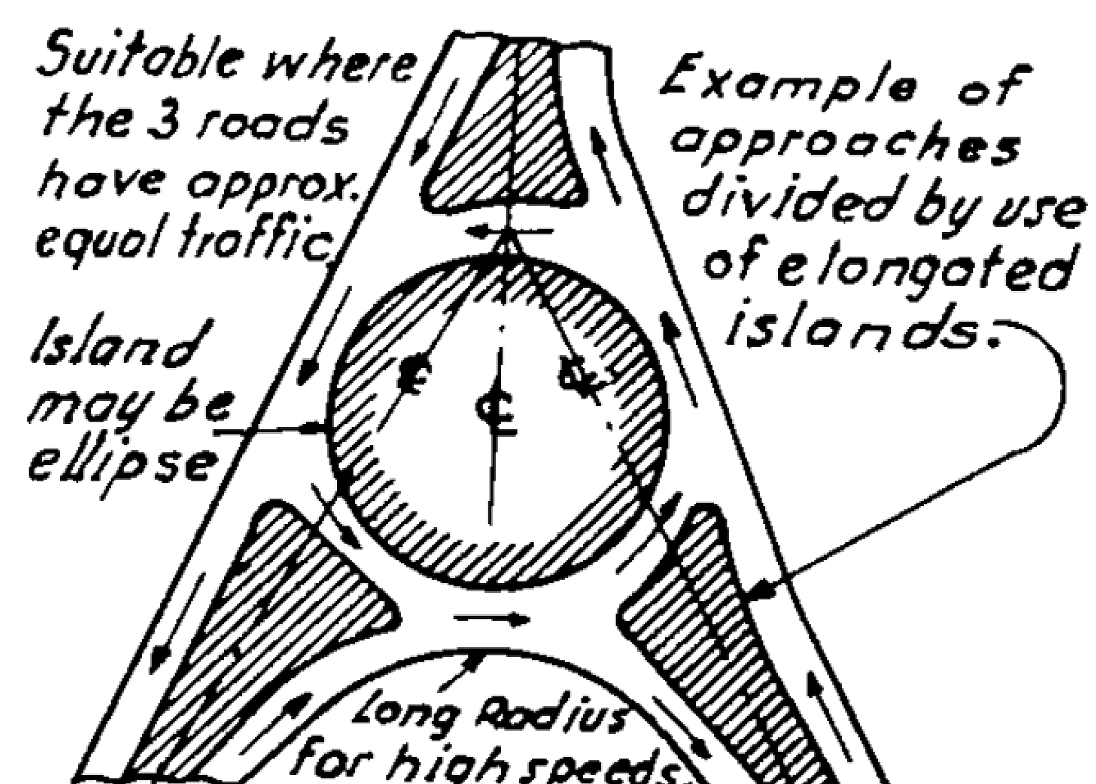
NOTES: Rotary type crossings are adaptable for traffic density of from 500 to 5000 vehicles per hr. (Sum of all roads).
Grades of roads approaching and within rotary - preferably under 3%, in no case over 5%.
Radii of curves at entrances and exits designed according to Intersections at Grade Data, Pg. 3-65, using Rotary design speed of 0.7 design speed of highest speed Radial Road.
Outer curbs concentric with central island to be avoided wherever possible.
Superelevation should not exceed 0.06' (3/4") for Rotary Roadway nor 0.10' (1 1/4") for exits, entrances or approaches.
The rotary and approaches should preferably be lighted at a higher intensity than the radial roads. See Pg. 3-89.
Curbs may be omitted at rural rotaries or initially in stage development (provide contrasting shoulders).
Provide lighted or reflecting signs, as follows: (1) Warning signs on radial roads. (2) Directing signs or arrows. (3) Route and destination signs. (4) Control signs where needed.



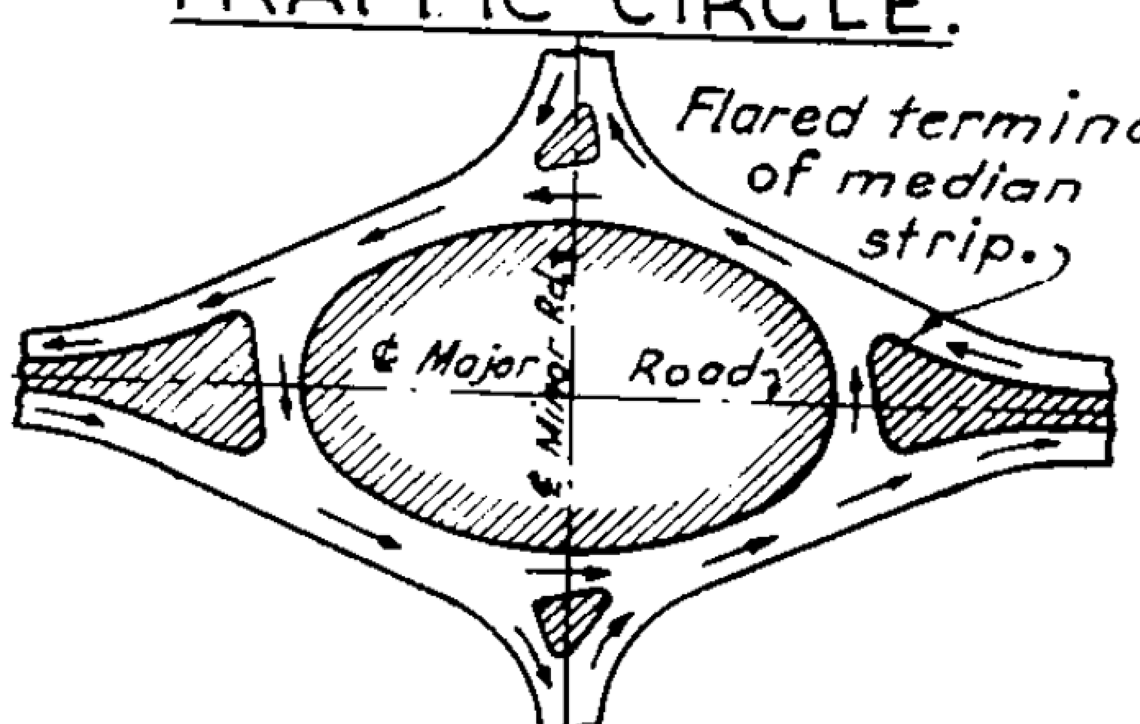
TRAFFIC CIRCLE.



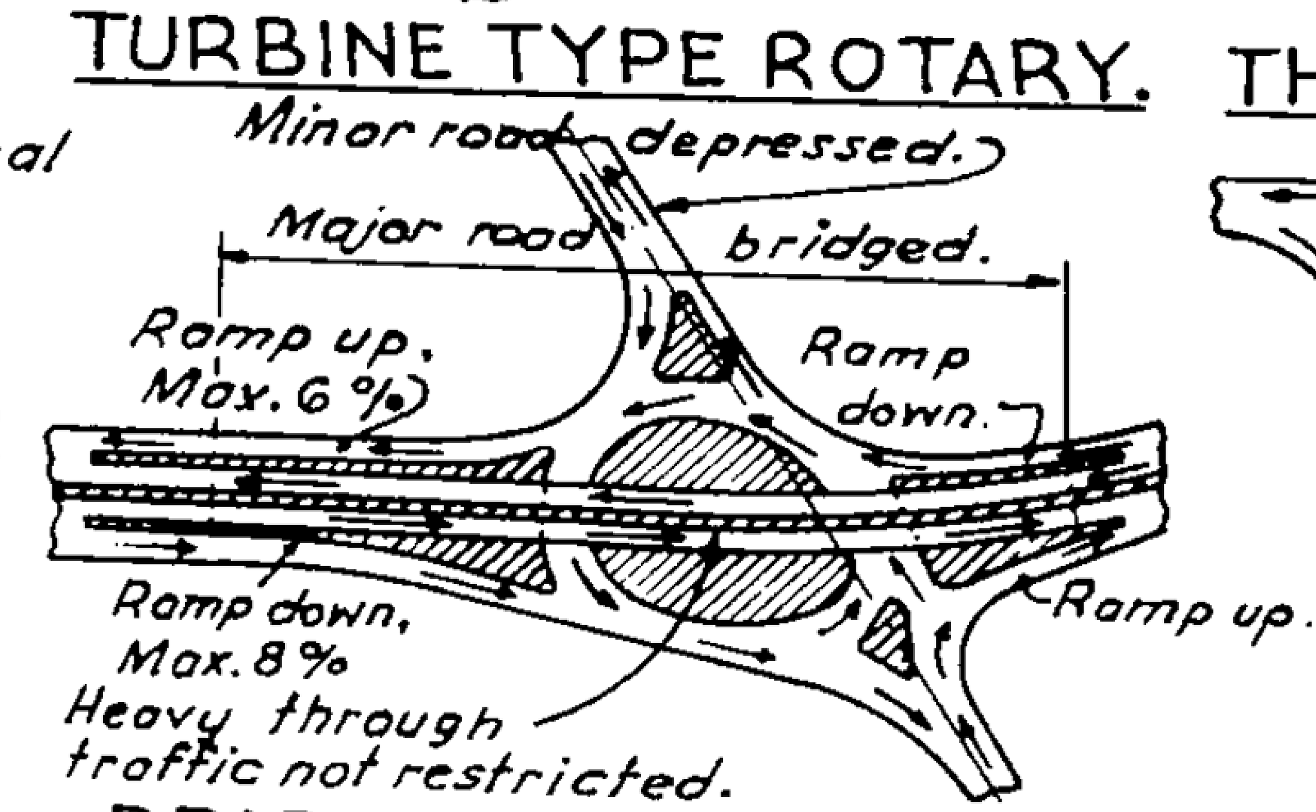
TURBINE TYPE ROTARY.



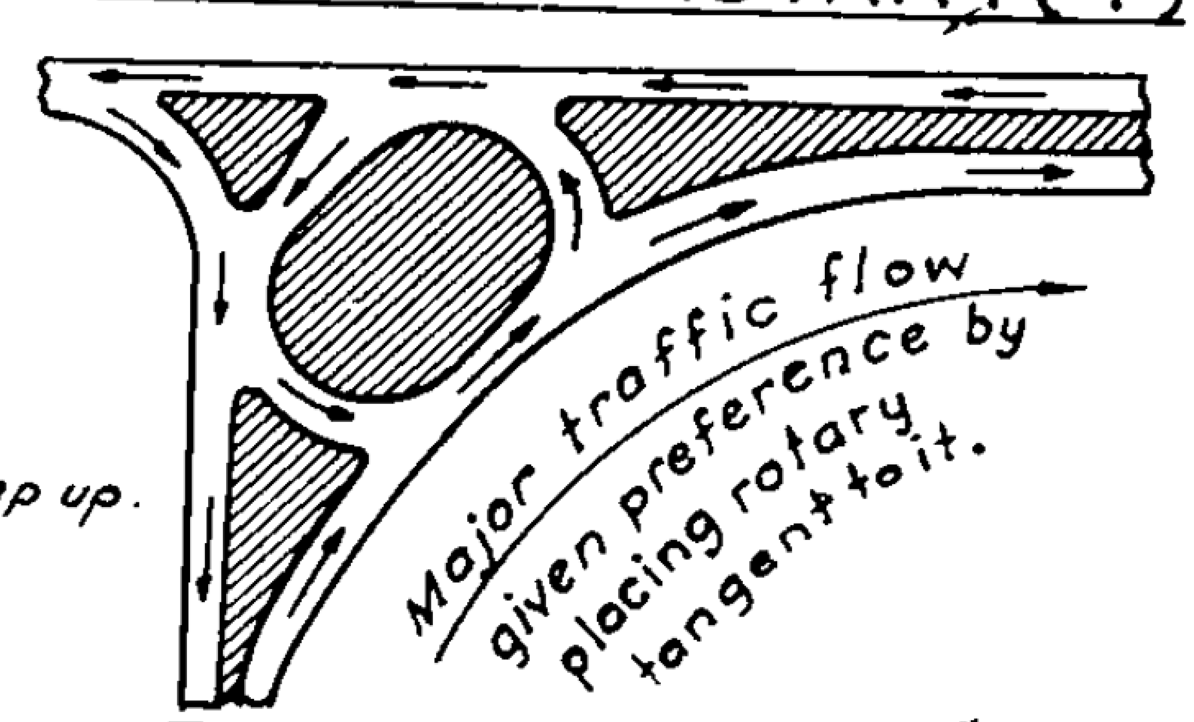
THREE ROAD ROTARY ("Y").



MAJOR-MINOR ROTARY.
Center island elongated to facilitate flow of traffic on major road.



BRIDGED ROTARY.
Through-traffic on viaduct
See Pg. 3-67 for clearances, grades etc.



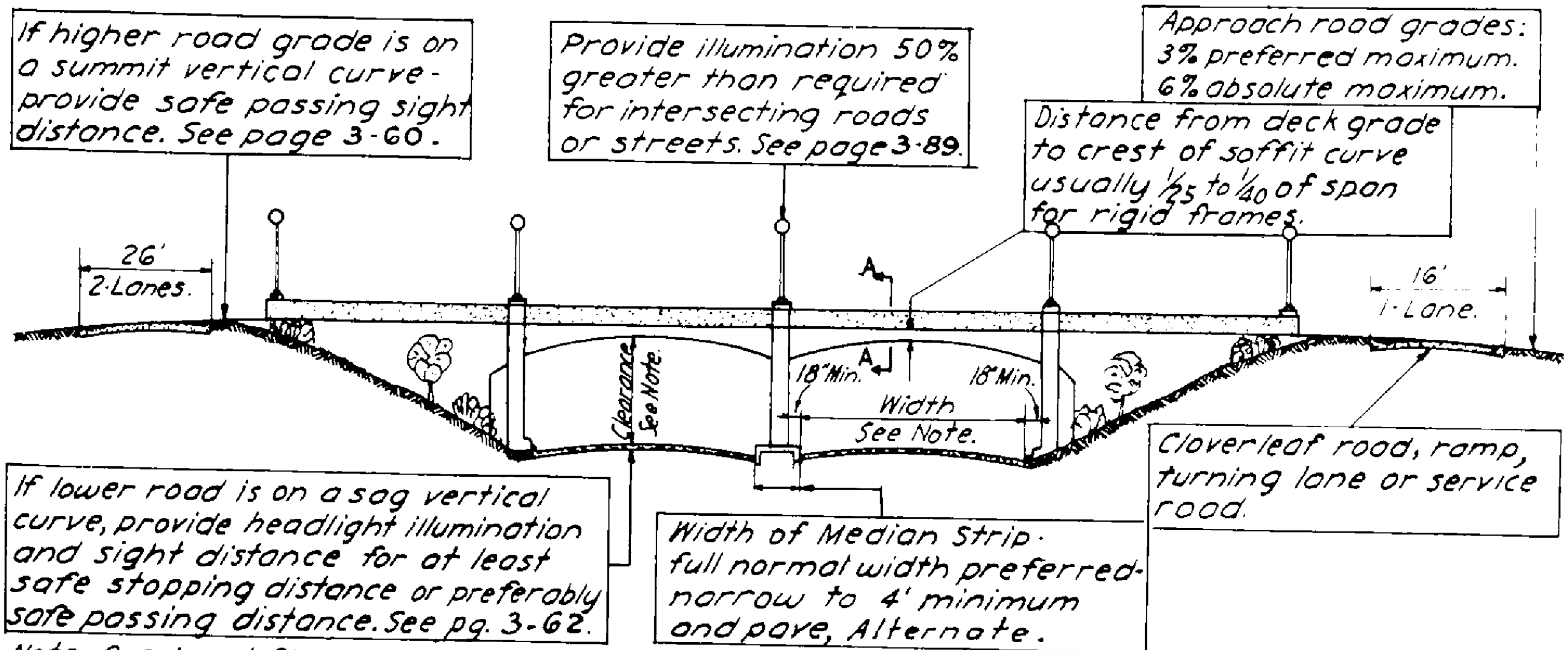
ROTARY AT "T".
Rotary treatment applied to "T" intersection.

FIG. B - ROTARY INTERSECTION DESIGNS - DIAGRAMMATIC.*

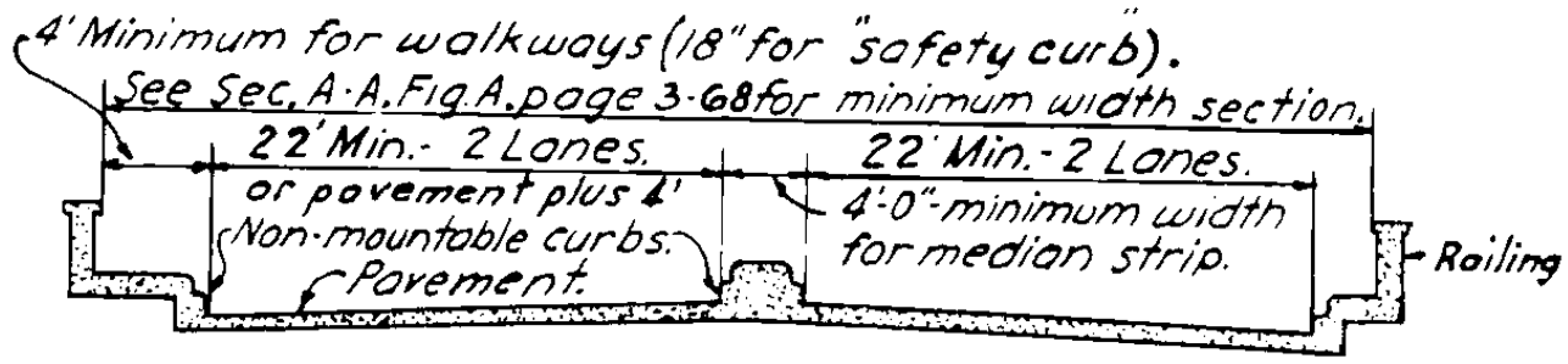
Design data shown in Fig. A apply to all types. Principles may be applied to crossings that are not fully developed Rotaries. Rotaries should be limited to roads of design speed 60 m.p.h. or under.

*Adapted from A Policy on Rotary Intersections, A.A.S.H.O., Washington, D.C.

ROADS – GRADE SEPARATIONS – 1



Note: Overhead Clearance: For pavement - 14'-0" minimum; at shoulders - 12'-6" minimum.
Width - Face to Face of curbs, or if curbs are omitted, face to face of walls.
Preferable - Full width of approach road pavement plus width of shoulders.
Absolute minimum 22'; but not less than approach pavement plus 4'.



Railing height not less than 2'-6" above adjacent roadway or not less than 3' above sidewalk less 1/2 width top rail.

SECTION A-A

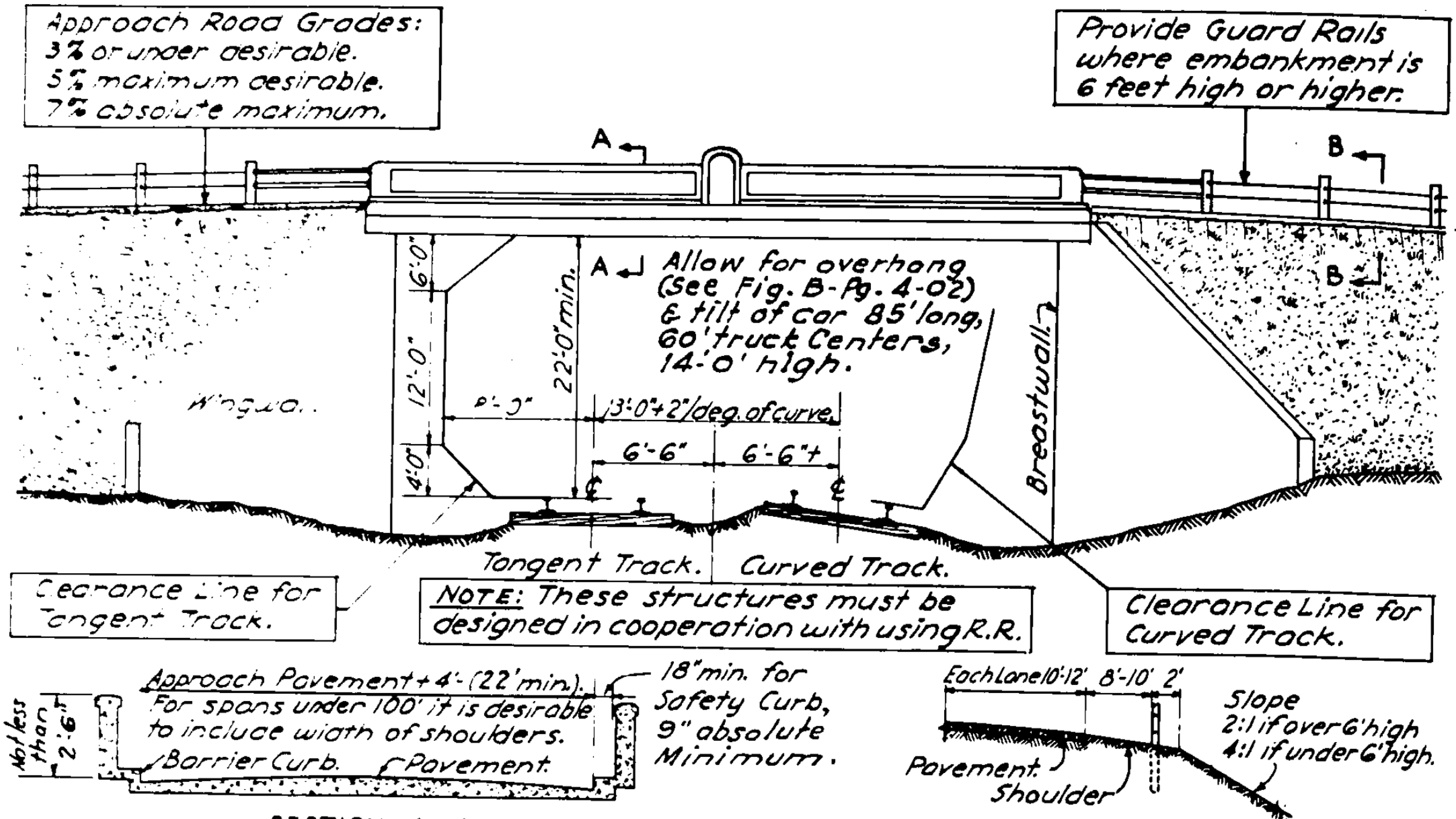
FIG. A - GRADE SEPARATION - HIGHWAY OVER HIGHWAY.

TABLE B - CHECK LIST FOR ALL TYPES OF GRADE SEPARATIONS.

MINIMUM ANGLE OF CROSSING.	45° - Preferred. 30° - Absolute Minimum.	MEDIAN STRIP WIDTH.	Minimum 4' wide.
APPROACH ALIGNMENT.	Curves under 4° desirable, 6° maximum.	SIDEWALKS.	One side, rural; both sides, urban. Min. 18" to 24" safety walk.
HORIZONTAL CLEARANCE - ROADS.	22' Minimum for 2 lanes, 44' Minimum for 4 lanes.	DRAINAGE AT SAG.	Gravity preferable, may require a lift pump.
VERTICAL CLEARANCE.	14'-0" for highways, Min. 22'-0" for railroads, Min.	ARCHITECTURE.	To harmonize with the surroundings.
GRADES. APPROACH	3% to 5% Max. - 6% to 7% absolute Max.	ILLUMINATION.	Units mounted at buttress, piers and abutments.
GRADES. RAMP	6% Max. up - 7 to 8% Max. down.		Provide 50% more lighting than for approach roads or streets.
SIGHT DISTANCE.	Safe passing preferable. Safe stopping Min. See pg. 3-60.		
HIGHWAY LOADING.	Usual minimum, H-20 for urban; H-15 for rural.		
SUPERELEVATION.	Max.: 0.10 (1¼") normally. 0.08 (1") subject to ice & sleet.	PLANTING.	Low and natural. Not to obstruct vision nor to attract attention.
TURNING LANES.	Designed for 0.7 design speed of through road.	SIGNS.	Guide, Stop, Route & Warning.

References: Standard Specifications for Highway Bridges, A.A.S.H.O.
National Interregional Highway Committee, Washington, D.C.
American Highway Practice by L.I. Hewes.
American Railway Engineering Association.

ROADS - GRADE SEPARATIONS-2



SECTION A-A. HALF-SECTION B-B.

FIG. A - HIGHWAY OVER RAILROAD.

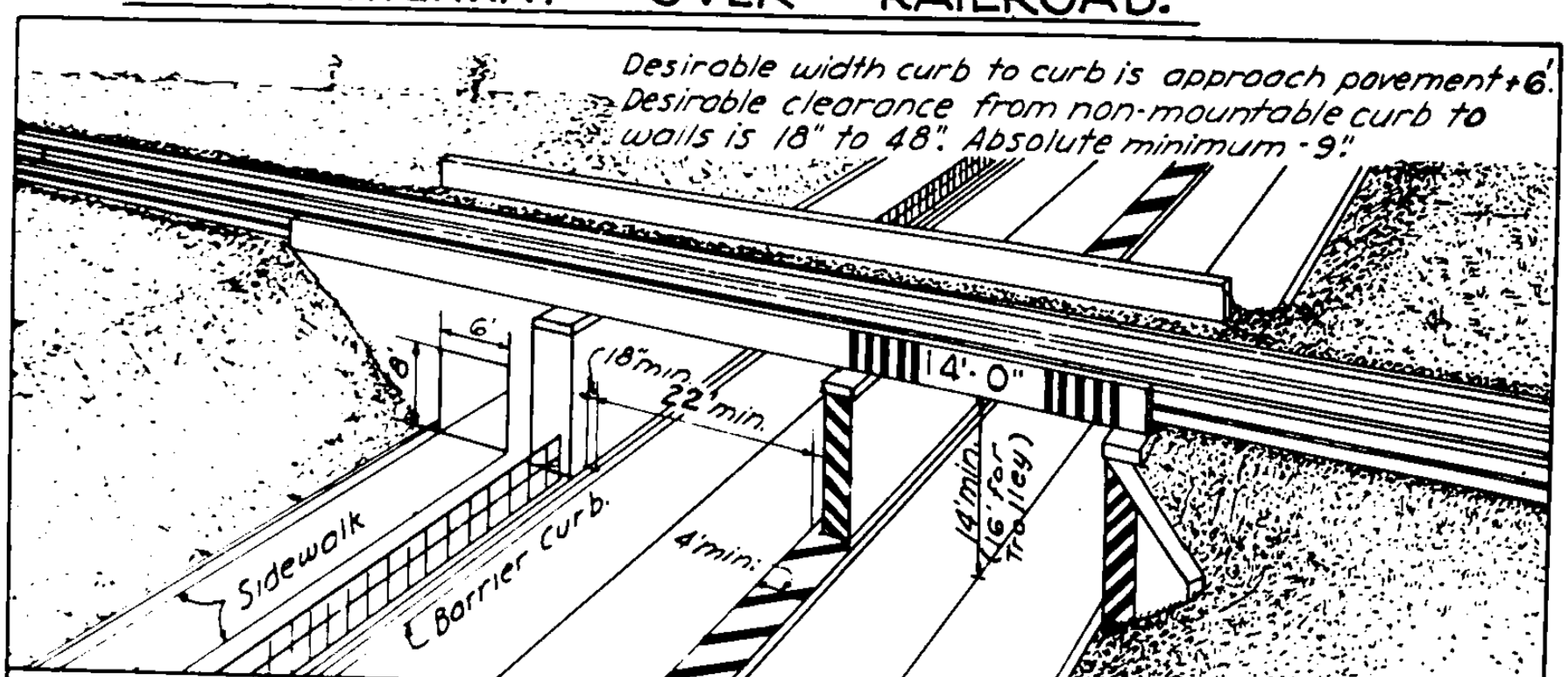


FIG. B - RAILROAD OVER HIGHWAY.

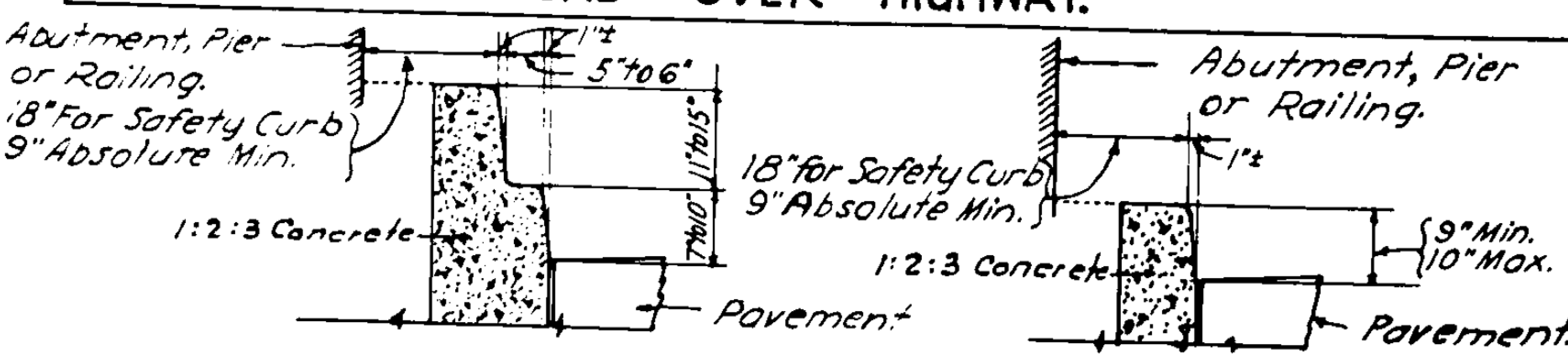


FIG. C - TYPICAL BARRIER CURBS.

Ref: See Page 3-67.

ROADS - CLOVERLEAFS

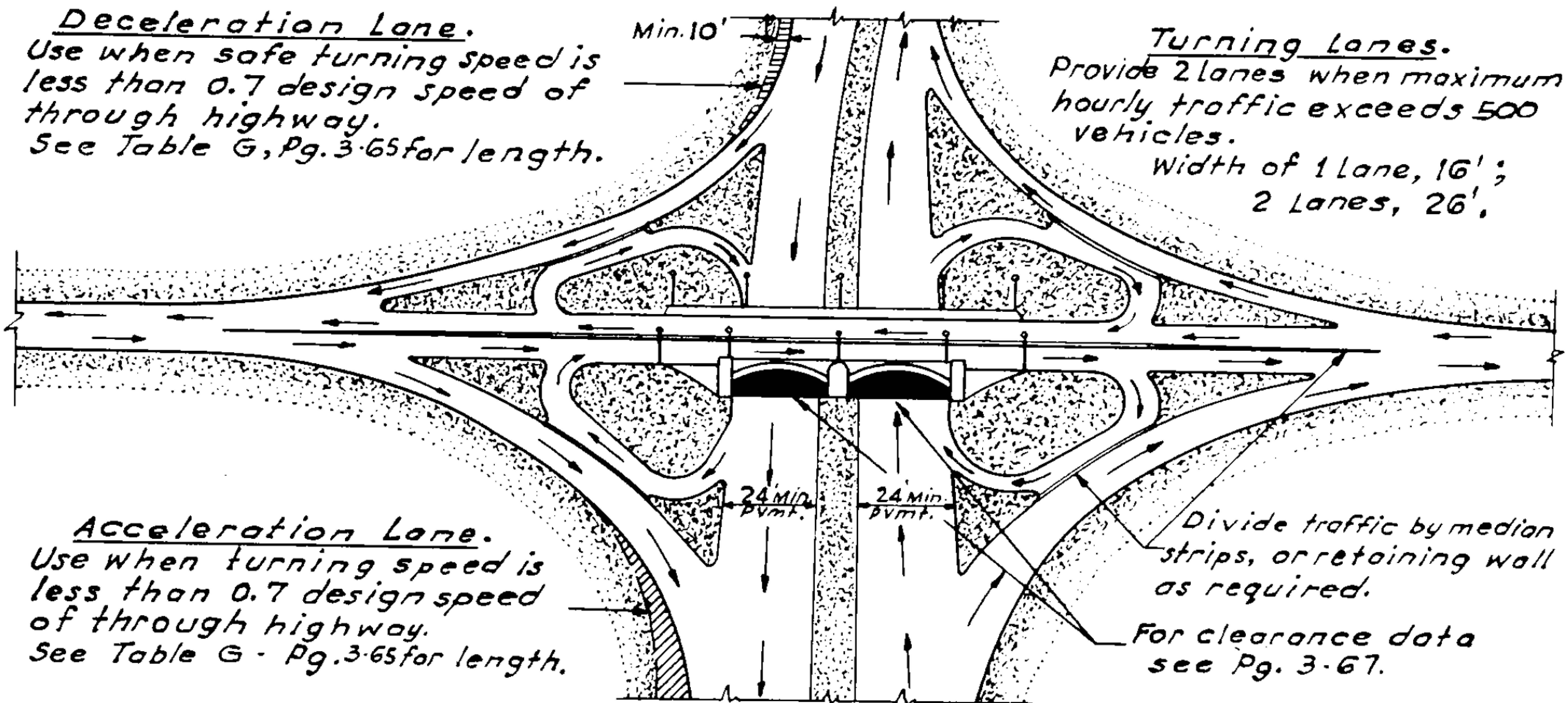


FIG. A - FULL CLOVERLEAF AT CROSSING.

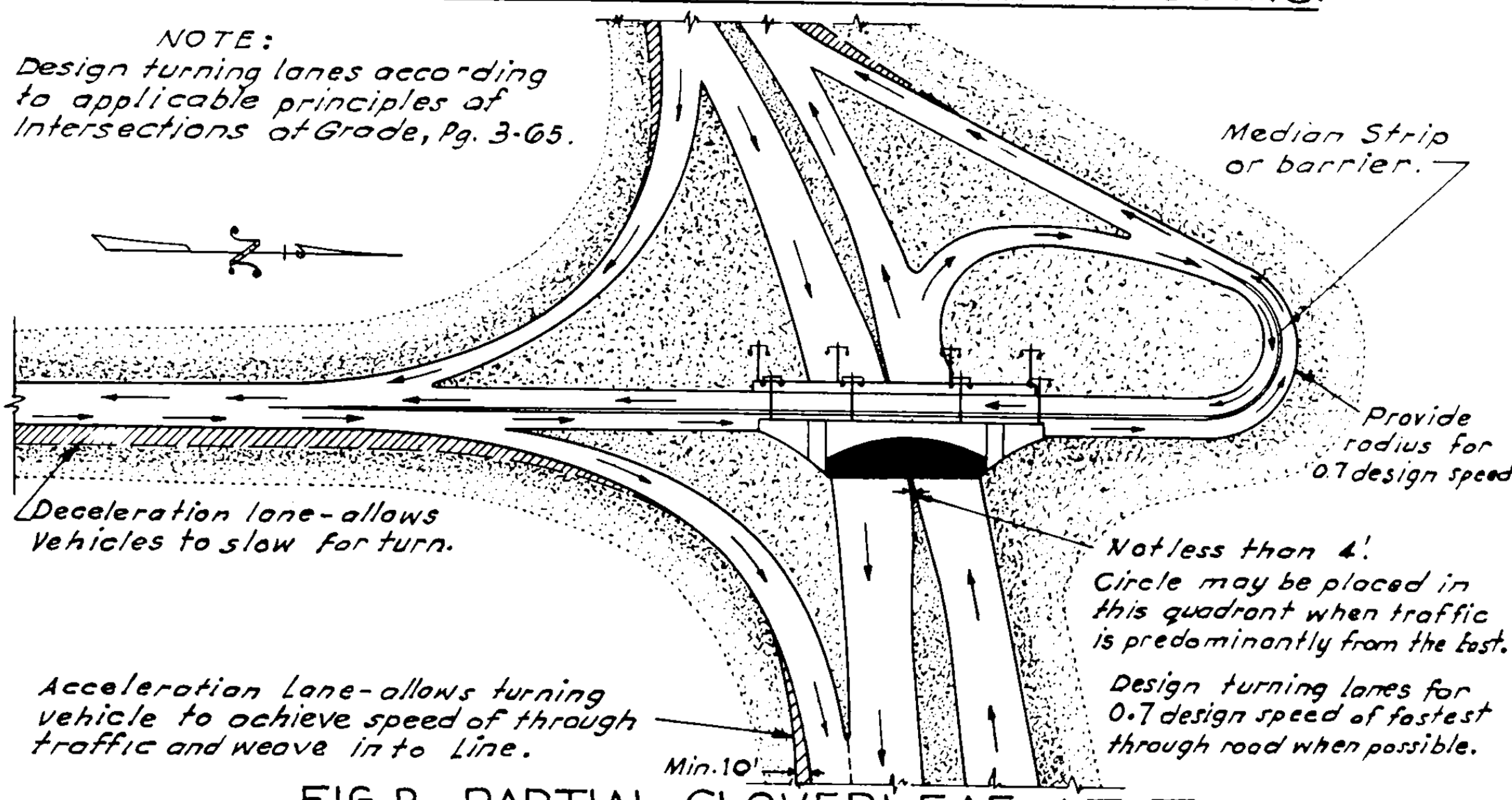


FIG. B - PARTIAL CLOVERLEAF AT T.

TABLE C - CHECK LIST - CLOVERLEAFS.

Alignment at intersection or approach.	Under 4° Curve desirable, 6° Curve maximum.	Superelevation per ft.	Max. 0.10' (1¼"), ice or sleet, 0.08' (1").
Vertical, Horizontal clearance at structure.	See Pg. 3-67.	Radius of turning lanes.	Design for 0.7 of design speed of through road.
Grades — Approach	3% grade desirable.	Median Strips.	4'0" minimum width.
Grades — Ramps	6% max. up; 7% max. down.	Illumination.	Lighted throughout at 50% more than approach roads.
Sight distance	At least safe stopping throughout.	Planting.	Not to obstruct vision.
Bridge loading	Preferably H-20 or H-20-S-16	Signs.	Guide, Stop, Route, Warning.

Ref.: See Page 3-67.

ROADS - DESIGN OF PAVEMENTS - 1

TABLE A - WHEEL LOADS FOR PAVEMENT DESIGN.*

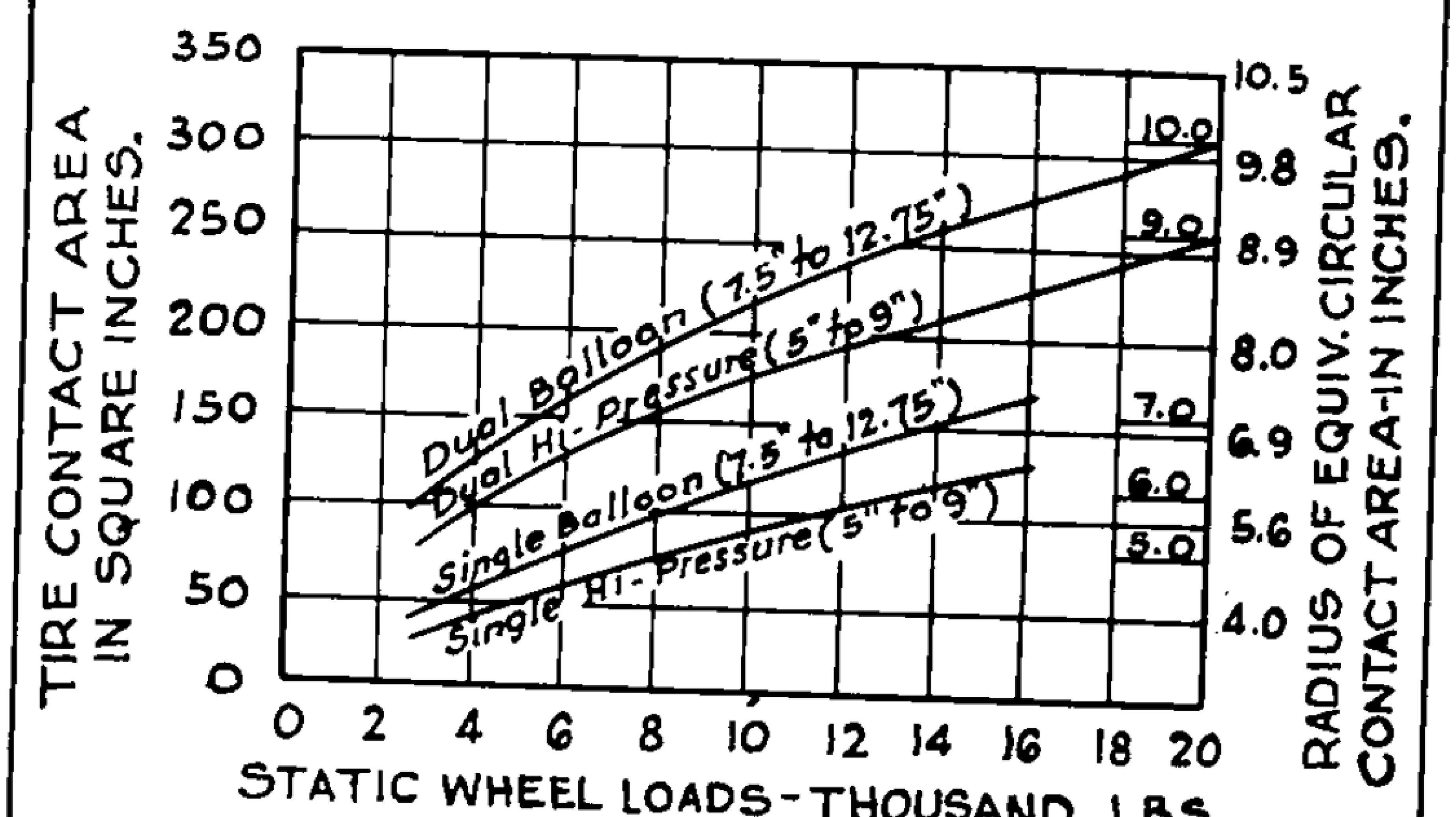
TYPE OF HIGHWAY, STREET OR ROAD.	WHEEL LOAD (STATIC)
Heavy duty urban routes, downtown business streets, State and County trunk lines through cities & urban zones, Class "AA", "A" and "B" roads with "T" traffic abnormally high.	12,000 Lb. (85 to 100 lb./sq. in.).
Heavily traveled rural routes, principal city streets, State and County trunk line roads in rural zones. Class "AA", "A" and "B" roads with "P" or "M" traffic.	10,000 Lb. (80 to 90 lb./sq. in.).
Roads and streets carrying only occasional 8000 lb. wheel loads (A.A.S.H.O. & P.R.A. maximum and legal limit in many states) with moderate volume of mixed traffic. Class "C" and "D" roads with "P" or "M" traffic.	7,000 lb. (70 to 85 lb./sq. in.).
Roads and streets carrying a light volume of passenger vehicle traffic with occasional light commercial vehicles. Class "E" or "F" roads with "P" or "M" traffic, private roads & drives.	4,000 Lb. (60 to 75 lb./sq. in.).

NOTES: Wheel load selected should be based on local laws and regulations, and if possible on traffic studies of load intensity and frequency. Pavement design is based on the wheel load and not on the gross weight of vehicle. Rigid pavements are designed with a safety factor (usually 2) allowing practically unlimited stress repititions caused by the design load. Thus an occasional overload up to as high as twice the design load will not be destructive. Flexible pavements, while not adapted to such exact analysis, will also carry occasional overloads if conservatively designed. Dual wheels are considered as one wheel load and one contact area if tires are within 3' centers.

TABLE B - IMPACT FACTORS

STATIC WHEEL LOAD	DUAL HI-PRESSURE	DUAL BALLOON
** 4,000 Lbs.	2.05	1.70
** 5,000 "	1.80	1.54
** 6,000 "	1.67	1.43
** 7,000 "	1.56	1.37
** 8,000 "	1.48	1.31
** 9,000 "	1.41	1.27
**10,000 "	1.36	1.24
12,000 "	1.3±	1.2±

Speed 50 m.p.h., pavement reasonably smooth.



$$\text{Unit pressure in p.s.i} = \frac{\text{Wheel loads in lbs.}}{\text{Contact area in inches.}}$$

FIG. C - TIRE CONTACT AREAS & RADII.**

For use in pavement design formulas and selecting size of bearing plates for field load tests.

*Reference: The Design of Street Pavements, R-153, Portland Cement Assoc., Chicago, Ill., & Reinforced Concrete Pavements, R.D. Bradbury, Wire Reinf. Institute, Washington, D.C.

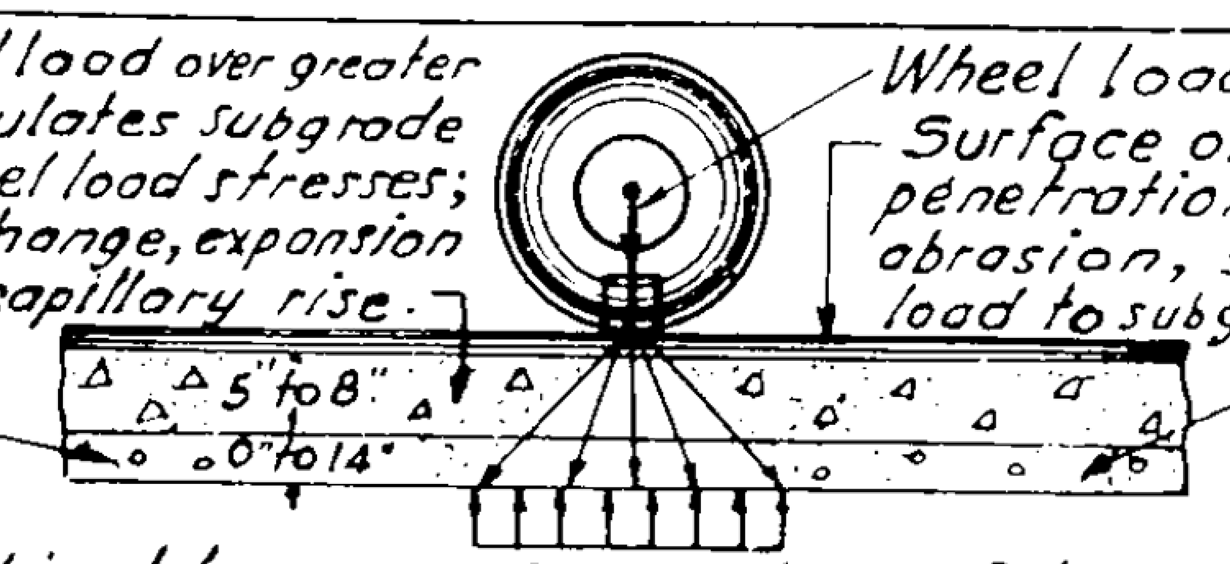
** Adapted from American Highway Practice by L.I. Hewes, Vol. II.

ROADS – DESIGN OF PAVEMENTS-2

Base Course: Distributes wheel load over greater area of sub-base or subgrade; insulates subgrade from frost penetration; resist wheel load stresses; protects pavement from volume change, expansion & softening of subgrade; prevents capillary rise.

Wheel load exerted upon surface.

Surface or Pavement: Seals base against penetration of surface water; resists ravelling, abrasion, shear; provides traction; transmits load to subgrade & base, reduces tractive resistance.



Sub-base required over fine grained silt, clay and plastic soils (A-4 to A-7) and for areas and soils subject to frost heave and excessive moisture.

Sub-base: Provides drainage; resists frost heave; resists shrinkage and swelling of subgrade; increases structural support; distributes load; prevents infiltration or pumping of subgrade.

FIG. A – FUNCTIONS OF PAVEMENT, BASE AND SUB-BASE.

FACTORS - SELECTION OF RIGID OR FLEXIBLE TYPE.	
RIGID (CONCRETE)	FLEXIBLE (BITUMINOUS)
Low maintenance cost - long life - high salvage value as base for future resurfacing - high visibility and reflection at night - spreads load over wide area - may be placed directly on weak or sandy subgrades - resists turning stresses - undamaged by oil or gas drip - low tractive resistance - can be designed and built close to tolerances.	Adaptable to stage construction - low cost types may be built with local labor, materials and equipment - easily opened and patched - low initial cost (except high types) - frost heave and settlement easily repaired - resists formation of ice glaze - great variety of types to fit a wide range of conditions - has no joints, has resilient riding qualities.

NOTE: Bitum. surface may be placed on rigid base. Concrete may be darkened & bitum. may be lightened in color.

PAVEMENT DESIGN

FLEXIBLE

SELECTION FACTORS: Use Table A, Pg. 3-72 to select the type of bituminous pavement, consider all of the factors listed as they pertain to the proposed road.

BEARING VALUES OF BASE & SUBGRADE: See Pg. 3-80 for CBR and load bearing value in p.s.i. for various soils and bases. Also see Soil Mechanics Section.

DESIGN METHODS.

PRACTICAL: Requires identification of soils into PRA group by appearance, texture & simple tests. Use Highway Research Board Table B - Pg. 3-72 to determine thickness of pavement, base and sub-base needed over each soil type. Customary sections for various Classes of Roads based on construction practice are shown on Pages 3-43, 44. These sections are adequate with sub-base added where necessary.

CALIFORNIA (CBR): Requires laboratory tests or assumption of CBR value of subgrade and available base and sub-base materials. Use the most economical combination with soils of lower CBR in bottom layers. CBR curves show directly the total thickness needed over any subgrade soil. The curves do not show the thickness necessary for frost heave prevention. As curves are based on 60 p.s.i. tire pressure, thickness should be increased 20% for pressures of 80 - 90 p.s.i.

ASPHALT INSTITUTE: Requires load bearing test or assumed bearing value of subgrade & base. Curves show the thickness of High Type Bitum. pavement needed over base or subgrade. Make economic study of pavement thickness balanced against cost of base or raising subgrade bearing value.

GRAY'S FORMULA: Requires bearing value of subgrade by load test or assumption. Formula gives the total thickness of granular base and pavement needed over subgrade. May be used in conjunction with Asphalt Institute curves to determine the base thickness needed by subtracting the pavement thickness from the total.

RIGID

SHEETS & WESTERGAARD: Requires load bearing test or assumed bearing value of subgrade or base. Sheets formulas give the pavement thickness. Take the nearest inch or 1/2 inch & check the stresses by Westergaard curves. (Check on corners by cantilever formula $t_e = \sqrt{\frac{3W}{S}}$.)
The customary sections for various Classes of Roads based on construction practice are shown on Pg. 3-44. When load tests are impracticable or subgrade conditions are uncertain these sections are recommended for Roads & Traffic as shown.

References: Portland Cement Assoc.; Asphalt Institute; Eng. Manual, Corps of Engineers, 1941 to 1943

ROADS — DESIGN OF FLEXIBLE PAVEMENTS-1

TABLE A – FACTORS FOR SELECTION & DESIGN.

FACTORS TO CONSIDER.	LOW TYPE BITUM. (SURFACE TREATMENT).	INTERMEDIATE TYPE BITUM.	HIGH TYPE BITUMINOUS.
	Prime & Seal, Blotter Coats, Carpet Coats, Armor Coats (under 1" thickness).	Penet. Macadam, Road Mix, Cold Plant Mix. Low Cost Hot mixes, Sand-Asphalt.	Central Plant Hot Mix, Sheet Asphalt Bituminous Concrete.
Wheel Loads See 3-37	4,000 to 7,000 See Note 1.	7,000 to 10,000	10,000 to 12,000 or over.
Traffic Character	Passenger or Mixed.	Passenger or Mixed.	Mixed or Truck.
Traffic Density	to 750 Daily	to 2,000 Daily.	To Road Capacity.
Probable Life	6 Months to 2 years	5 to 15 years.	15 to 25 years
Maintenance	Annual Seal - Continual Patching & Repair.	Occasional Seal. Intermittent patching & Repair.	Very little - Occasional Seal Coat & Patching.
Constr. Equipment Required.	Trucks, Drags, Spreaders & Distributor.	See Note 2.	Central Plant, Trucks, Mech. Spreaders, Heavy Rollers.
Labor Required.	Unskilled, Semi-Skilled & Equipment operators.	Unskilled, semi-skilled & Equipment Operators.	Unskilled, Semi-skilled & Highly skilled.
Aggregates.	Usually Local.	Usually Local.	High grade - May necessitate importing.
Bitum. Materials.	Liquid or Semi-Solid.	Liquid or Semi-Solid.	Solid Asphalts or Tars.
Initial Cost	Low	Medium.	High
Mainten. Cost	High	Medium.	Low
Type of Base Required.	Gravel, Sand-Clay, Crushed Stone, Stabilized soil, Lime Rock, Soil Cement.	Gravel, Sand-Clay, Crushed Stone, Stabilized Soil Caliche, Scoria, Shell or Slag.	Water or Dry Bound Macadam Bitum. Macadam, Soil Cement or Cem. Concrete.

NOTES: 1. Low and intermediate types may be used for heavy wheel loads or dense traffic for temporary or stage construction and over fills where settlement is expected.
2. Road Mix (Mix-in-Place): Graders, harrows, tillers, trucks, spreaders, loaders & distributors.
Plant Mix: Temporary or Travel Plant, spreaders, graders, trucks, loaders & rollers (optional).
Penetration: Crusher, Trucks, spreaders or graders, heavy rollers, drags & distributors.

EXAMPLE: Use of Table A - Given: Low initial funds, light traffic, rural area, provisions for maintenance, abundant local gravel. Required: Pavement type. Solution: From study of factors, either a prime & seal on gravel base with gravel cover or a gravel road-mix would be logical. If initial funds are ample, traffic is dense & heavy, area is urban consider Bitum. Conc. or Sheet Asphalt.

TABLE B – PRACTICAL DESIGN THICKNESS OF PAVEMENT BASE AND SUB-BASE.*

Compiled by Highway Research Board from State Highway Experience based on 10,000 lb. wheel loads.

MAJOR DIVISIONS SUBGRADE SOILS.	Coarse grained Sandy & gravelly soils.					Fine grained silt & Clay soils.			
CLASSIFICATION-SUBGRADE SOIL (PRA).	A-1-b Non-Plastic	A-1-a Plastic	A-2-a Non-Plastic	A-2-b Plastic	A-3	A-4 A-4-7	A-5 A-5-7	A-6	A-7
PAVEMENT	2"	2"	2"	2"	2"	2"	2"	2"	2"
BASE COURSE.	0"	5"	5"	6"	5"	8"	8"	8"	8"
SUB-BASE COURSE.	0"	0" to 12"	0"	0" to 12"	0"	2" to 14"	4" to 14"	0" to 14"	0" to 14"
TOTAL THICKNESS.	2"	7" to 19"	7"	8" to 20"	7"	12" to 24"	14" to 24"	10" to 24"	10" to 24"

NOTES: For detailed characteristics to identify soil classes, see Soils section. Pavement may be Surface Treatment, Road-Mix, Cold Plant Mix, Penetration or Central Plant Hot-Mix. When Surface Treatment is used the base thickness should be as shown plus 2" in lieu of pavement. Base course thicknesses as shown are for gravel, crushed stone, slag, sandy clay, sand-clay-gravel, caliche & lime-rock. For Soil Cement Base use 5" over A-1 plastic to A-3 and 6" over A-4 to A-7 subgrades. Sub-Base may be sand, gravel, cinders, slag, crusher-runstone, shale, screenings, stabilized local soil. The Plasticity Index of Base & Sub-base should not exceed 6 in any case. For frost protection the base & sub-base material should have under 8% passing a 200 mesh or under 3% passing 0.02 mm.

*Adapted from The Thickness of Flexible Pavements by Highway Research Board.

ROADS - DESIGN OF FLEXIBLE PAVEMENTS-2

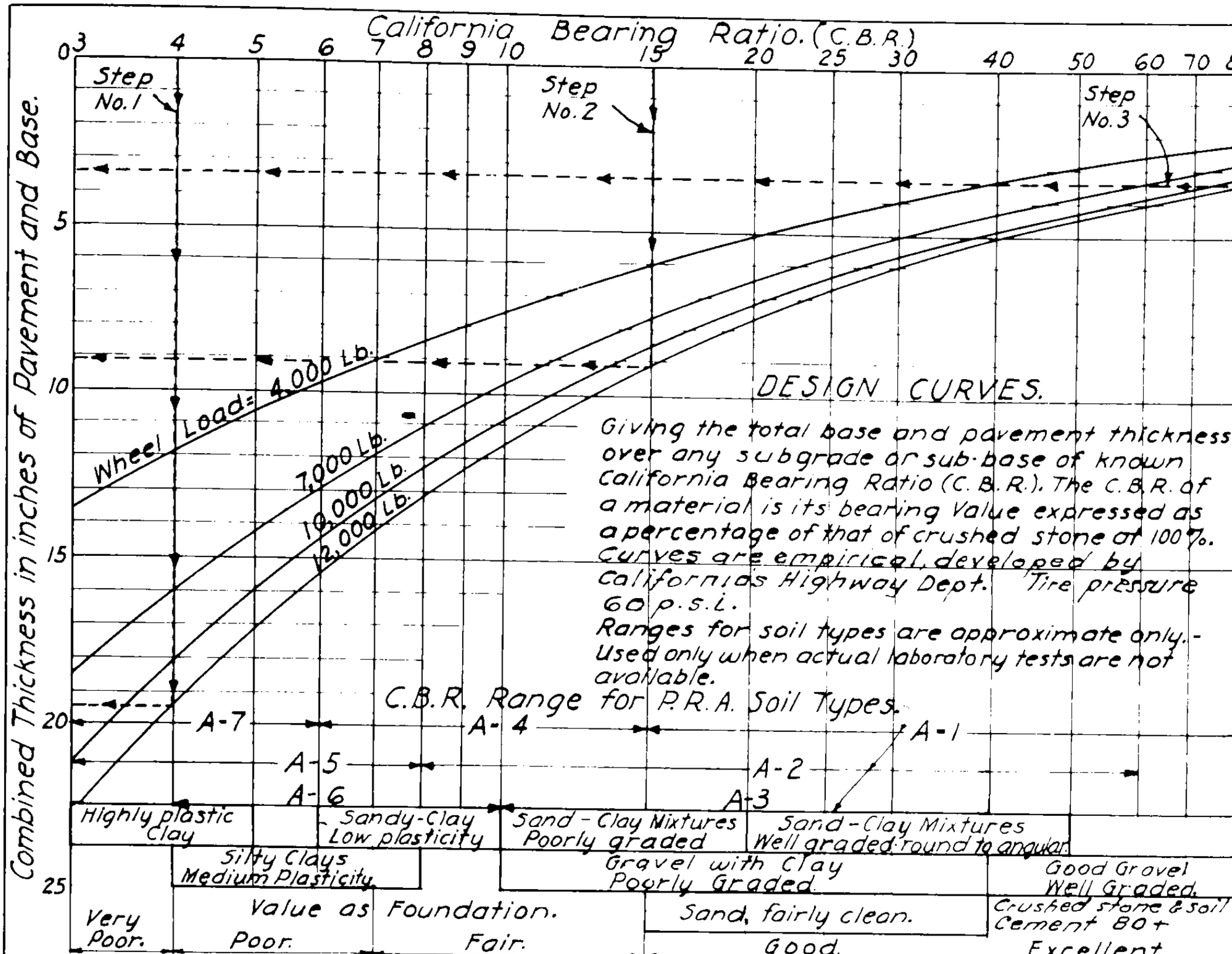
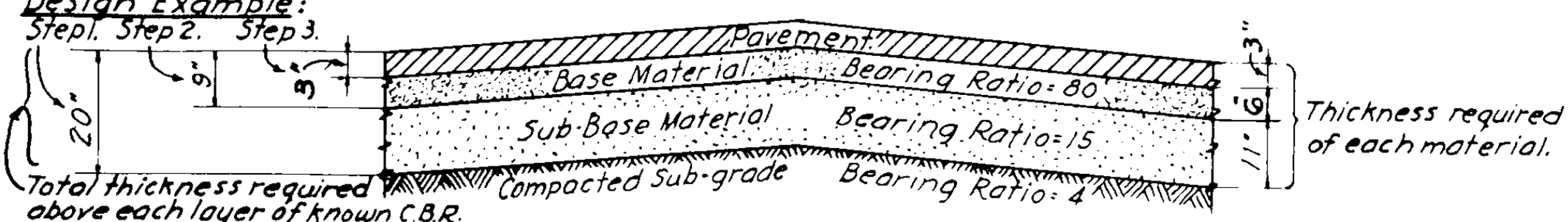


FIG. A - DESIGN OF PAVEMENT & BASE THICKNESS BY CALIFORNIA METHOD.

NOTE: Using base material with a high C.B.R. for lower layers in place of material with a lower C.B.R. does not decrease the total base thickness, which is governed by the C.B.R. of the subgrade. In any case the combined thickness of pavement and non-frost action base material such as clean sand or gravel should be from ½ to full depth of frost penetration. The minimum C.B.R. of the upper base material for a depth of 5" to 8" beneath the pavement should be 80 for 10,000# and 12,000# wheel loads and 40 to 65 for 4,000# and 7,000# wheel loads.

Design Example:



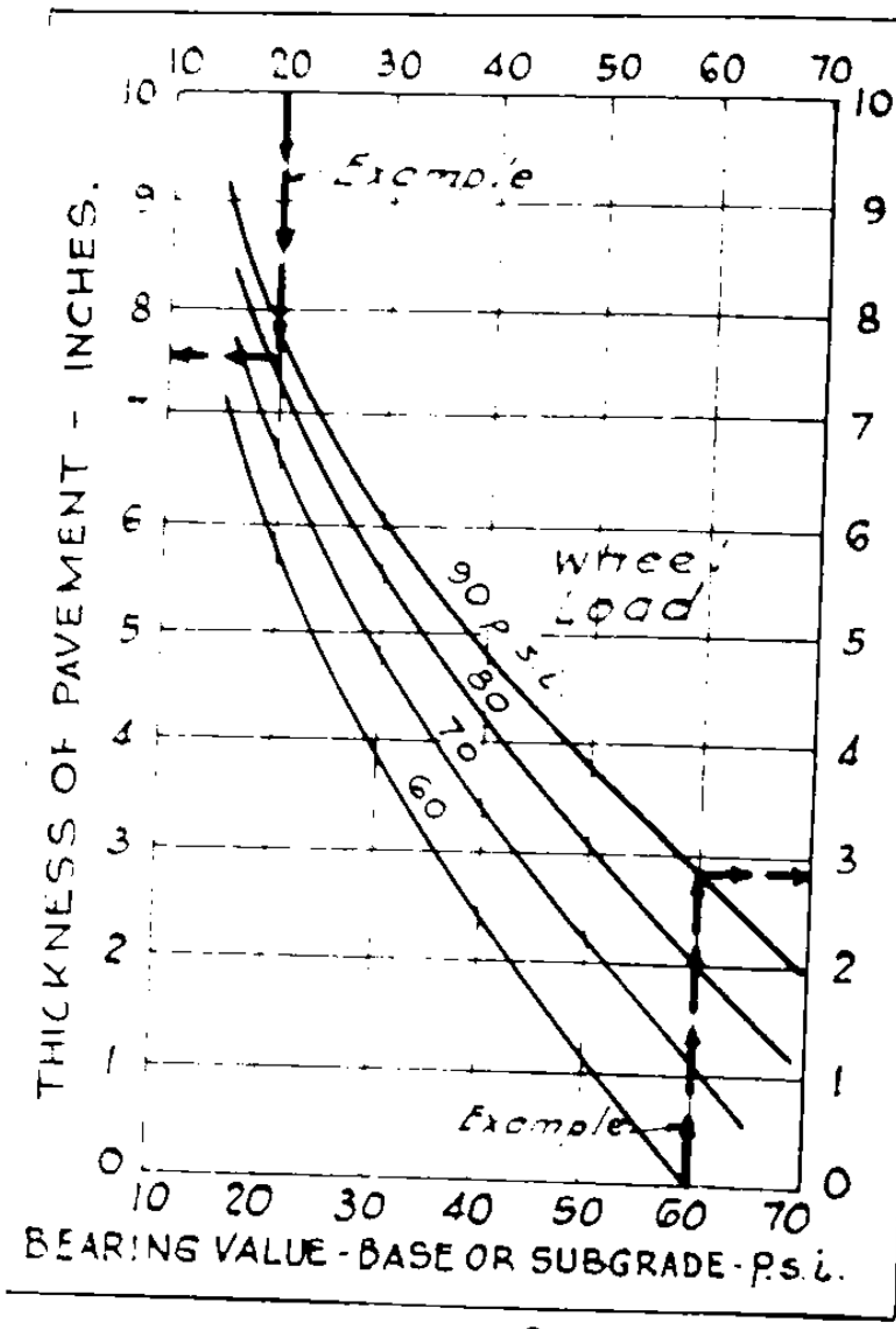
Given: - A heavy duty Class "A" highway, "T" traffic with up to 12,000# wheel loads, a plastic clay subgrade with a C.B.R. of 4. Available sandy borrow for sub-base with a C.B.R. of 15. Available base material with a C.B.R. of 80.

Required: - Thickness of sub-base, base and pavement.

Solution: - Step 1; from the 12,000# curve the required total thickness of base and pavement above the subgrade (C.B.R. of 4 percent) is 20 inches. Step 2; the minimum depth of more stable material (higher C.B.R.) above the sub-base (C.B.R. of 15 percent) from the 12,000# curve is 9" very nearly. Step 3; The required thickness of pavement over the base (C.B.R. of 80 percent) is 3", say 2" of bit. concrete binder and 1" of bit. concrete wearing course.

References: A. Casagrande, O.J. Porter, Eng. Manual of U.S. Eng. Dept. 1941 to 1943 & Eng. News Record, Jan. 28 1943.

ROADS - DESIGN OF FLEXIBLE PAVEMENTS-3



ASPHALT INSTITUTE DESIGN CURVES.

Giving the total thickness of Asphaltic Concrete pavement required over any base or subgrade of known bearing value. The bearing value is based on the p.s.i. on a circular plate (of the same contact area as that of the design wheel load) causing a deflection of 0.5 inch – See Soils Section for evaluation of subgrade & bases and approximate bearing values of soils & bases. See Page 3-70 for wheel loads & contact areas.

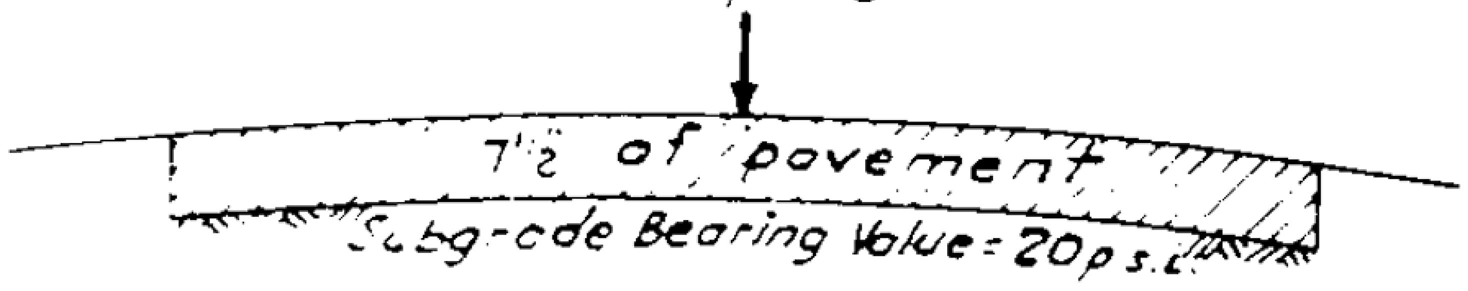
DESIGN EXAMPLE.

Given: A heavy duty Class "A" highway, "T" traffic with 12,000# wheel loads (90 p.s.i.), contact area 133 sq. in., Subgrade with bearing value of 20 p.s.i. Available base material with bearing value of 60 p.s.i. Cost of pavement is 30 ¢ and of base is 12¢ per sq. yd. for each inch of thickness (assumed for example only).

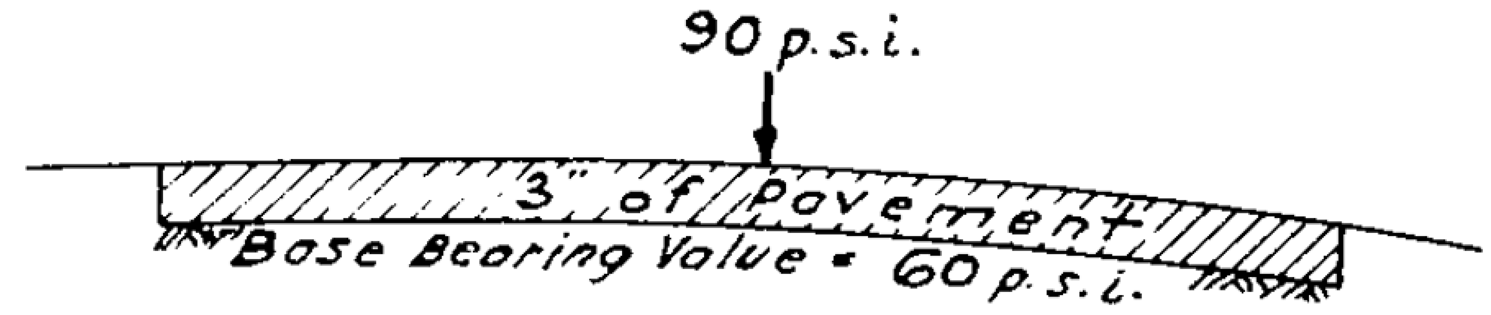
Required: Alternate designs; Nº 1, all pavement & Nº 2 pavement & base.

Solution: From curves, 7½" of pavement is required over 20 lb. subgrade and 3" is required over 60 lb. base of 4½" thickness.

(See problem Fig. B below) ∴ Cost of Design Nº 1 = 30 x 7½ = $ 2.25 per sq. yd. Cost of Design Nº 2 = (30 x 3) + (12 x 4½) = $ 1.44 per sq. yd.



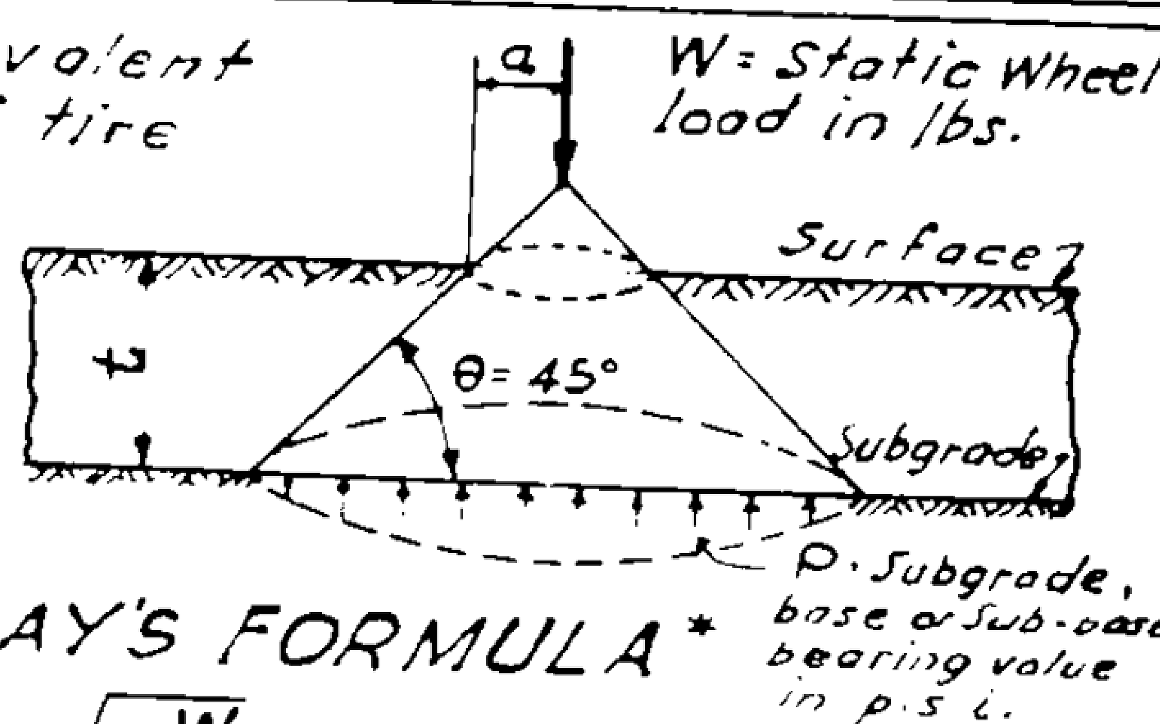
DESIGN Nº 1 - PAVEMENT OVER SUBGRADE.



DESIGN Nº 2 - PAVEMENT OVER BASE.

FIG. A - CURVES FOR THICKNESS OF ASPHALTIC CONCRETE PAVEMENT.

a = radius of equivalent circular area of tire contact.
t = thickness of flexible pavement and base in inches.



GRAY'S FORMULA*

$$t = .564\sqrt{\frac{W}{p}} - a$$

GRAY'S FORMULA.

Flexible pavement design methods (such as C.B.R. and formulas by Harger & Bonney, Hawthorne, Housel, Downs, Goldbeck, etc.) are based on the intensity of pressure on the subgrade varying in same inverse ratio with the thickness of pavement and base. Gray's formula is typical in which the load "W" is distributed downwards conically with an angle of load distribution θ of 45° as shown. The unit pressure and required bearing value at any plane may be computed. Or, if the bearing value is known the required pavement and base thickness may be computed.

DESIGN EXAMPLE.

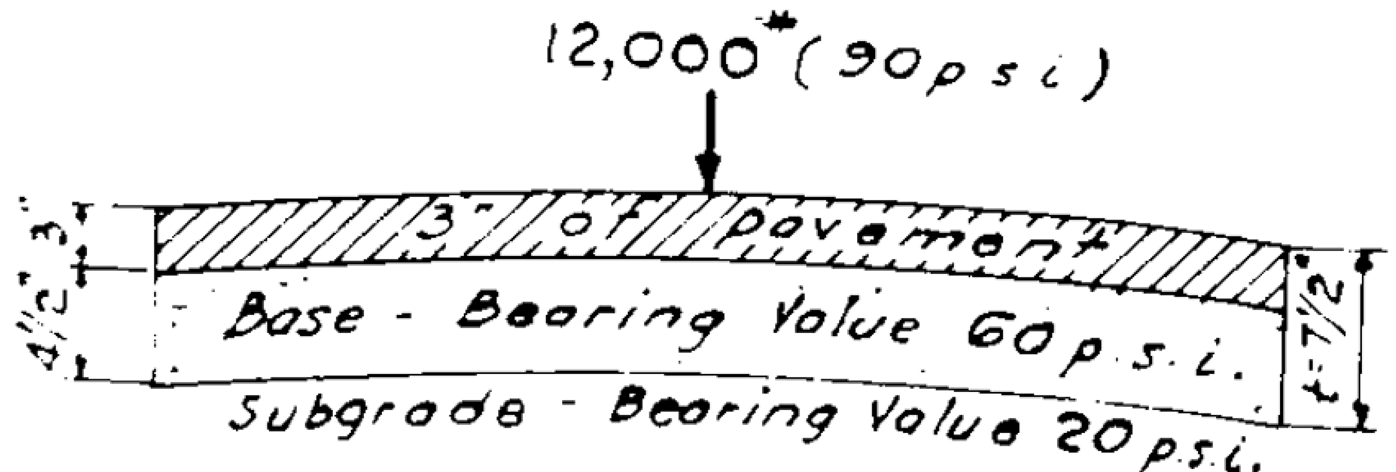
Given: W = 12,000 lbs. (90 p.s.i.) Contact area = 133 sq. in.

$a = \sqrt{\frac{133}{\pi}} = 6.5''$ (or from Fig. C - Pg. 3-70).

p = 20 p.s.i. (W, a & p from Example Fig. A).

Required: Thickness of base (t-3") in Example Fig. A.

Solution: $t = .564\sqrt{\frac{12{,}000}{20}} - 6.5 = 7\frac{1}{2}''$ ∴ $t - 3'' = 4\frac{1}{2}''$



DESIGN Nº 2 - PAVEMENT & BASE.

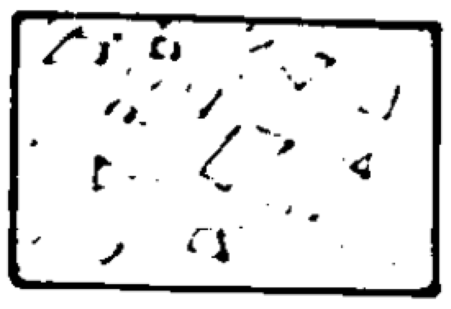
FIG. B - THICKNESS OF FLEXIBLE PAVEMENT AND BASE.

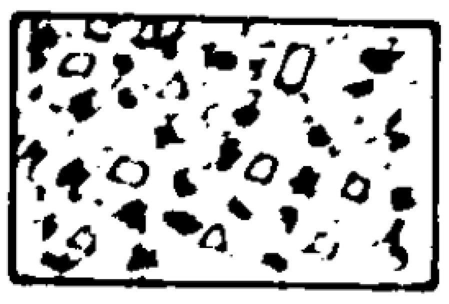
NOTE: Curves Fig. A are based on the confining effect of Asphaltic Concrete Pavement and should not be used for low type pavement or base thickness. Formula Fig. B is suitable for granular bases. Concrete bases should be designed by Rigid Pavement Formulas, Pg. 3-80.

Reference: Research & Construction Series, The Asphalt Institute, Design of Flexible Pavement; Public Roads, Vol. 18, Nº 11. * Bernard E. Gray, Chief Engr., Asphalt Institute.

ROADS - BITUMINOUS CONSTRUCTION

I  *Open Type Pavements (Coated aggregate, may have voids). Penetration, Plant Mix or Mix-in-Place (Road Mix) of Crushed Stone and Bitumen.*

II  *Dense Mats (Not theoretically graded) (Low Cost). Mix-in-Place, Plant Mix or Pre Mix, Road Mix of aggregates graded coarse to fine and Bitumen.*

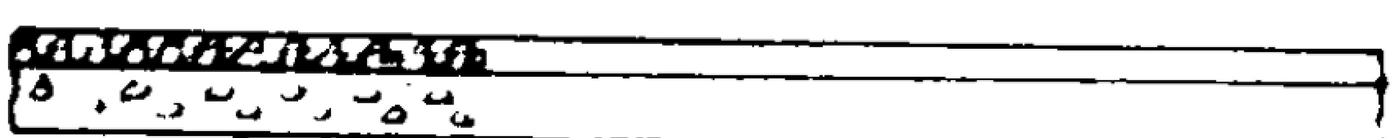
III  *Dense Theoretically graded Pavements - Bituminous Concrete. Plant Mix of Coarse and Fine Aggregate, Mineral Filler & Bitumen.*

IV  *Dense Theoretically graded Sand Pavements - Sheet Asphalt. Plant Mix of Sand passing #10 mesh to #200, Mineral Filler and Bitumen.*

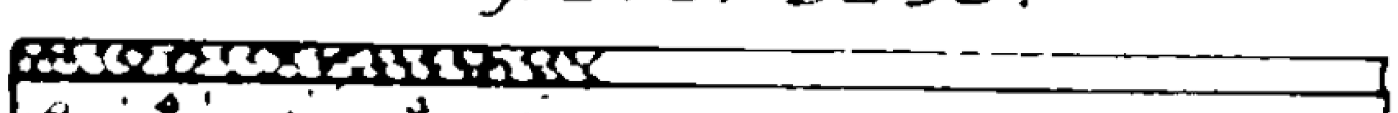
V  *Dense Sand Mats (Not theoretically graded) - Sand Asphalt. Plant Mix or Mix-in-Place of Sand passing #4 mesh and Bitumen.*

BITUMINOUS PAVEMENT TYPES. *

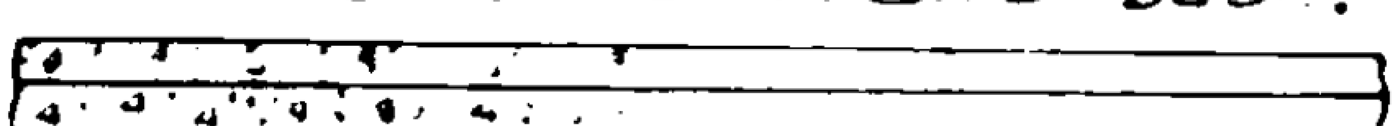
LOW TYPE
Bituminous surface treatment
6" - 8" Limerock, gravel, crushed stone or soil cement stabilization.



INTERMEDIATE TYPE
2"-2½" Mix-in-Place (Road Mix)
6" or more gravel base.

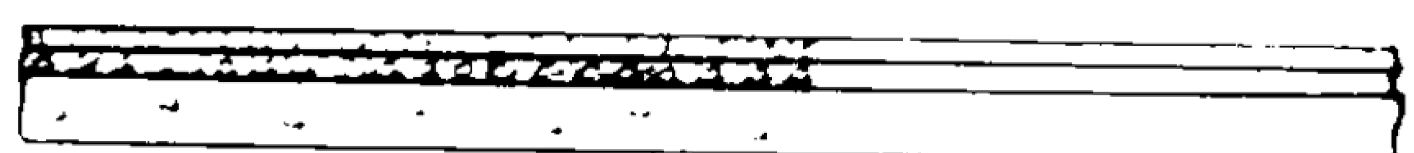


INTERMEDIATE TYPE
3" Penetration Surface
4" to 6" Crushed stone base.

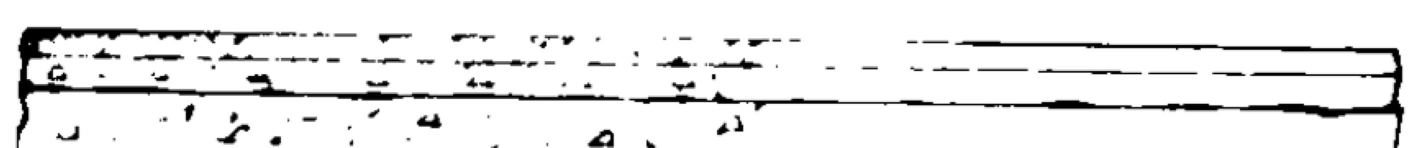


BITUM. CONCRETE - HIGH TYPE
2" Bituminous Concrete surface.
3" Bituminous Concrete base.

BITUM. CONCRETE - HIGH TYPE.
1½" Bituminous concrete surface.
1½" Bituminous concrete binder.
6-9" Crushed stone base.



SHEET ASPHALT - HIGH TYPE.
1½" Sheet asphalt surface.
1½" Asphalt binder course.
6-9 Portland cement concrete base.



RESURFACE - HIGH TYPE.
1" Sheet asphalt or bitum. concrete.
1½" Bituminous concrete binder.
sand or bituminous leveling course.
Existing pavement for base.

TYPICAL SECTIONS - BITUMINOUS ROADS

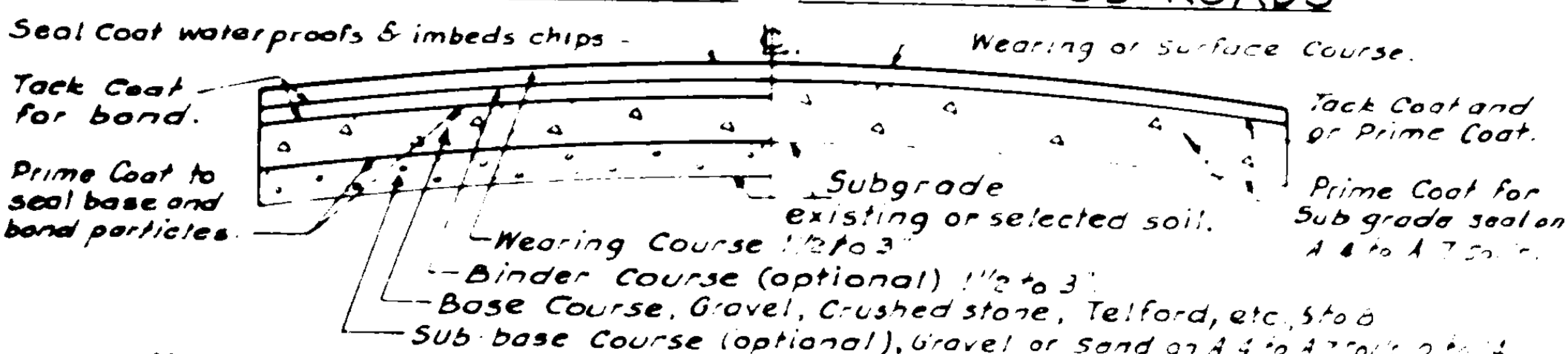


ILLUSTRATION OF ELEMENTS OF BITUMINOUS ROADS

* Adapted from Bituminous Construction Handbook by Barber Greene Co.

ROADS - BITUMINOUS MIXTURE DIAGRAMS-1*

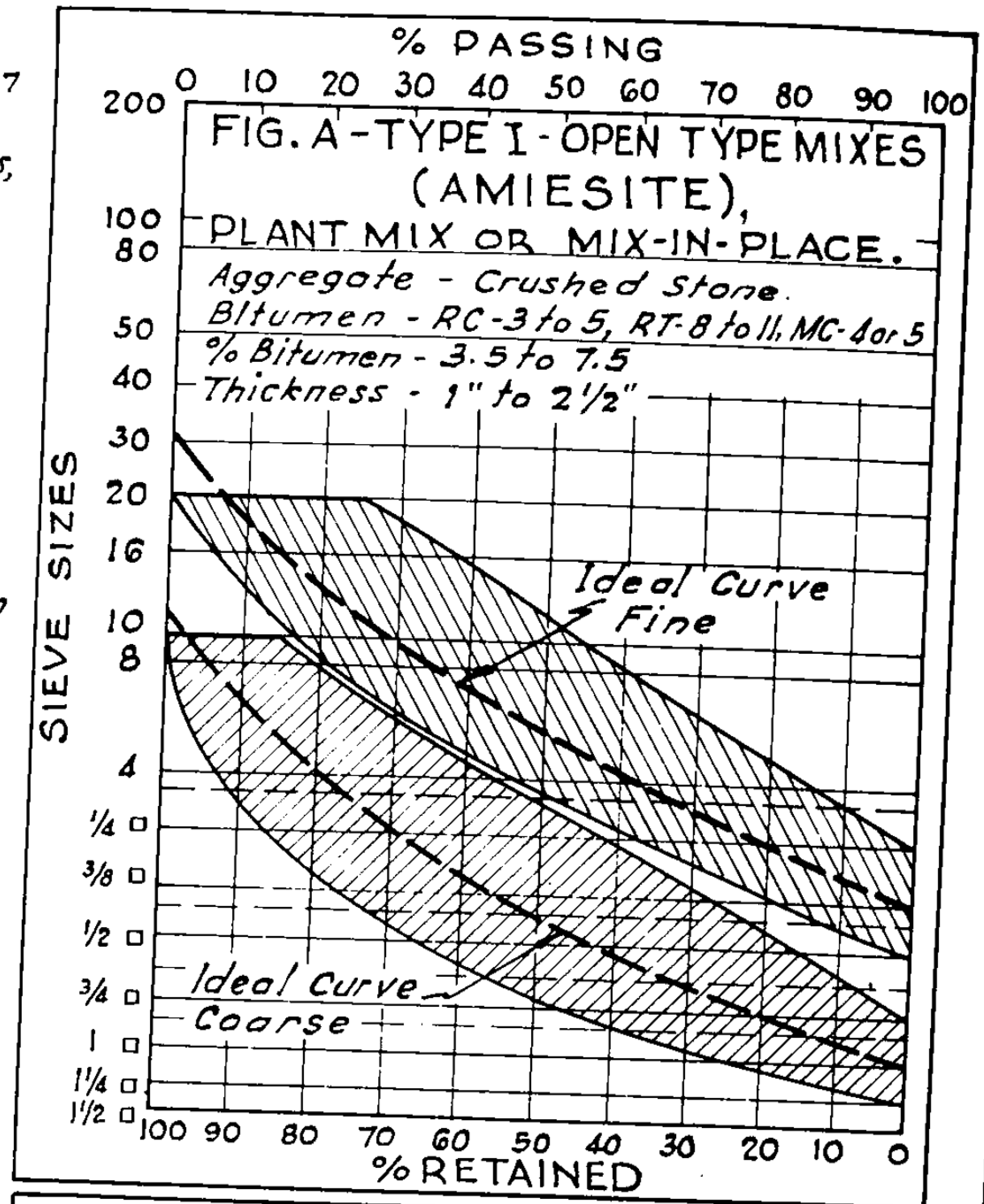
USE OF DIAGRAMS.

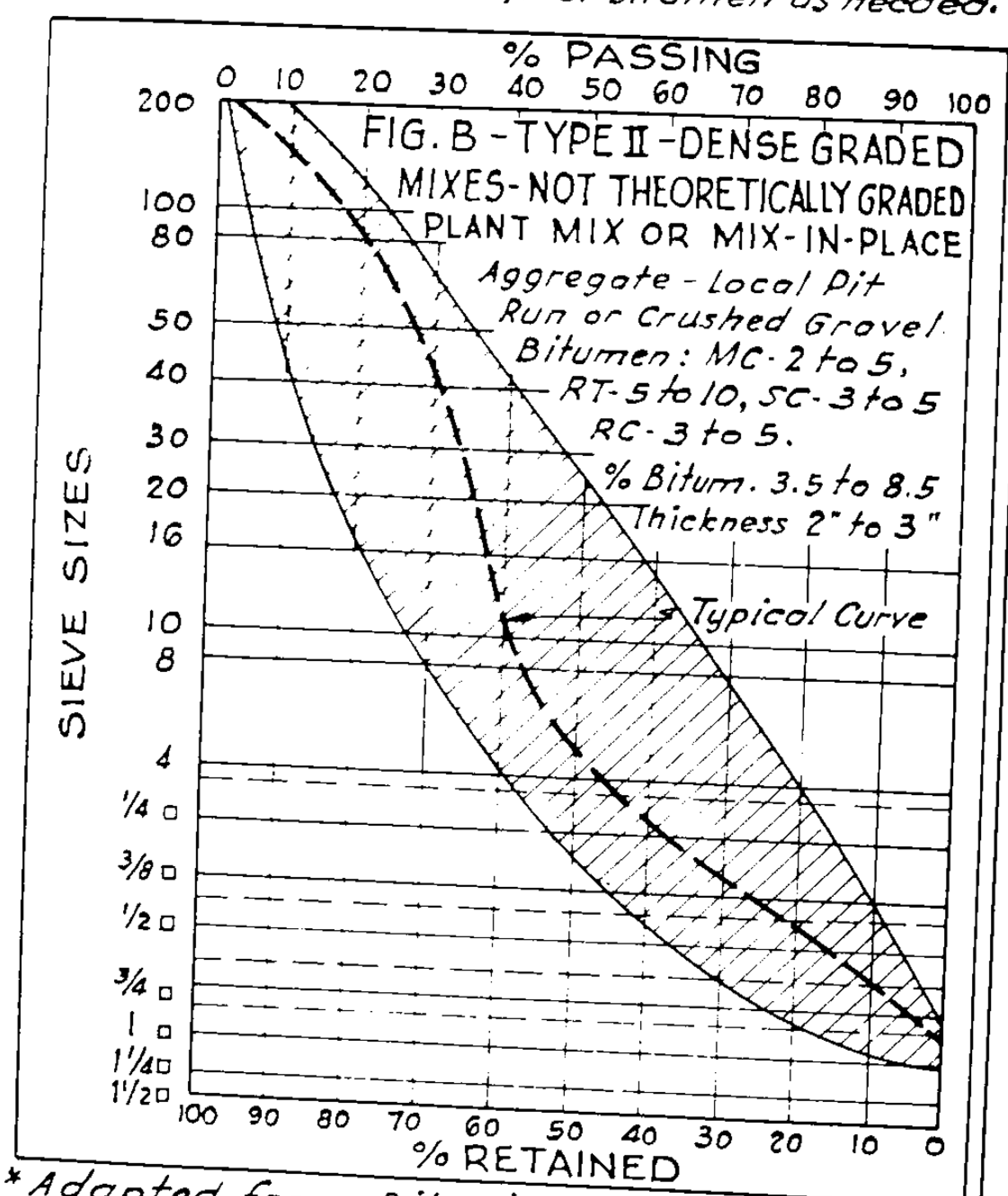
Diagrams on this Page and Page 3-77 show the proper range of aggregate gradation for Bituminous Pavements, Types I to V as given on Page 3-75. The type of aggregate, the type and percentage of bitumen, and the thickness practicable to construct in one layer are also shown.

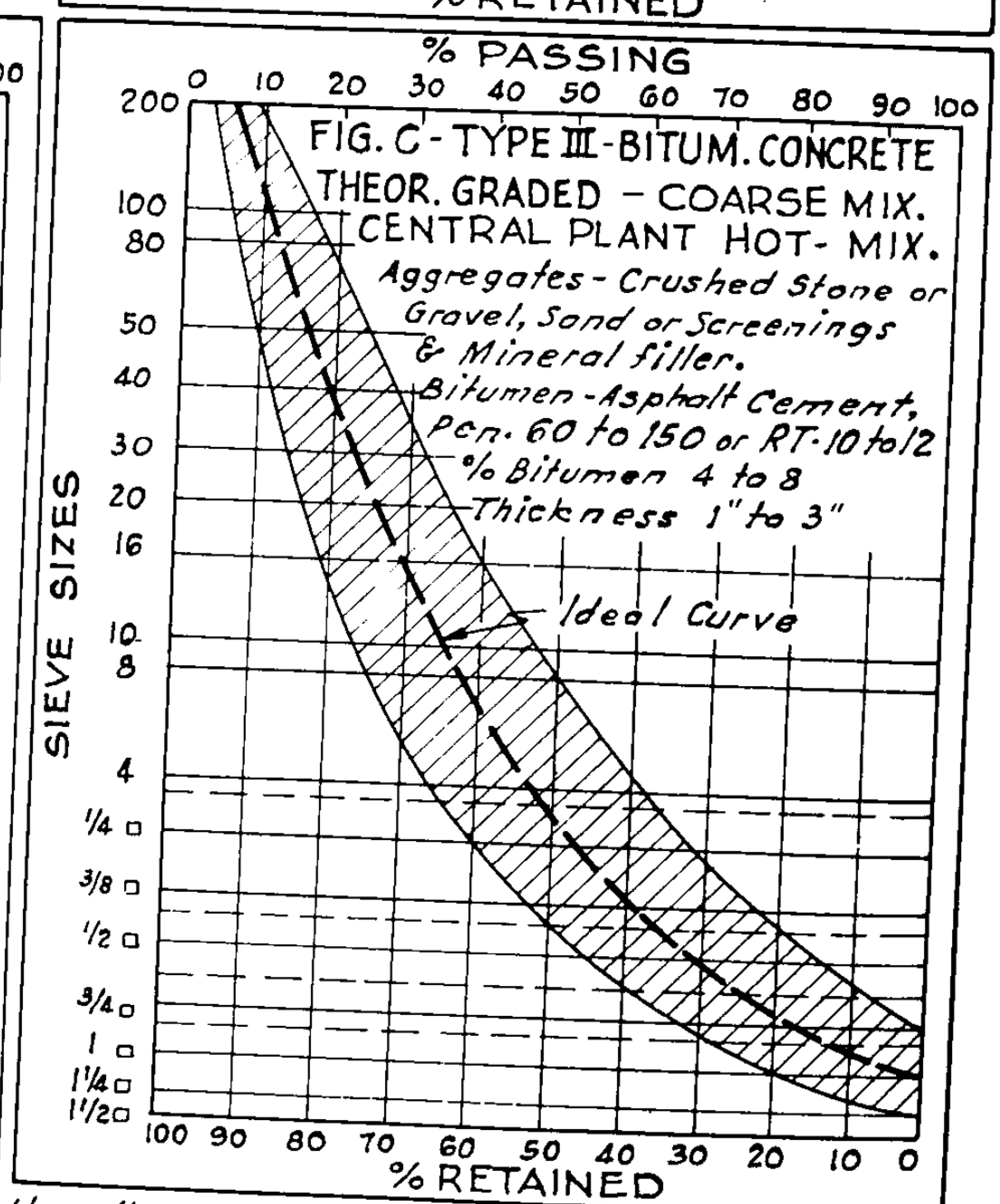
The gradation of the proposed aggregate should fall within the limits of the curves of the diagram for the type of pavement selected.

To Design a Mix: Make sieve test of aggregate. Plot on Chart. Adjust gradation if necessary, until gradation curve approximates ideal curve. Mix samples of aggregate with varying amounts of bitumen. Allow samples to stand exposed for several days and check stability, density and uniformity of aggregate coating. A fat, greasy, soupy, unstable mixture will indicate excessive bitumen. A dry, brownish, cracked, crumbly, mixture with uncoated particles will indicate deficient bitumen content.

To Control Mix: Plot daily sieve tests. Adjust gradation or % of bitumen as needed.



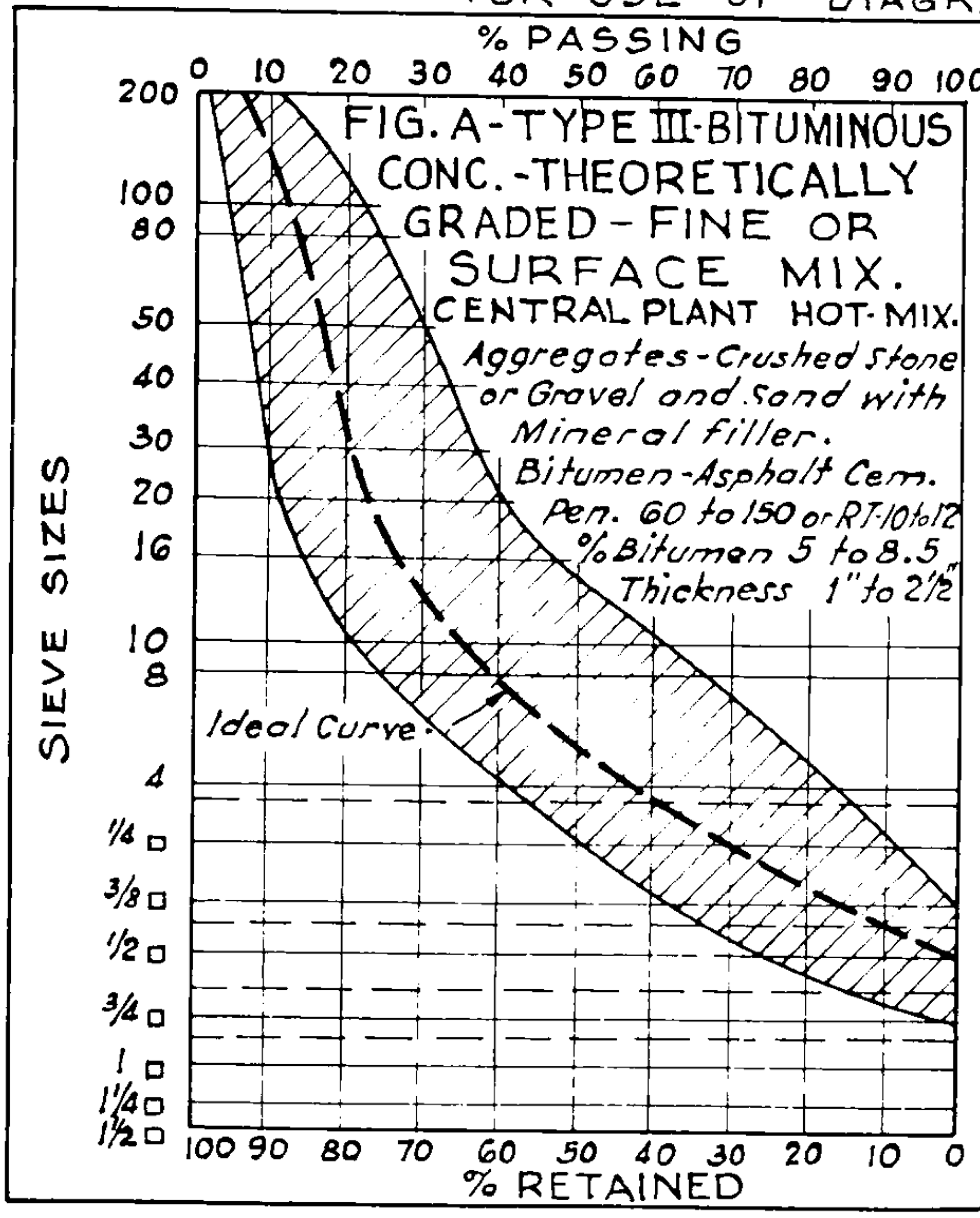


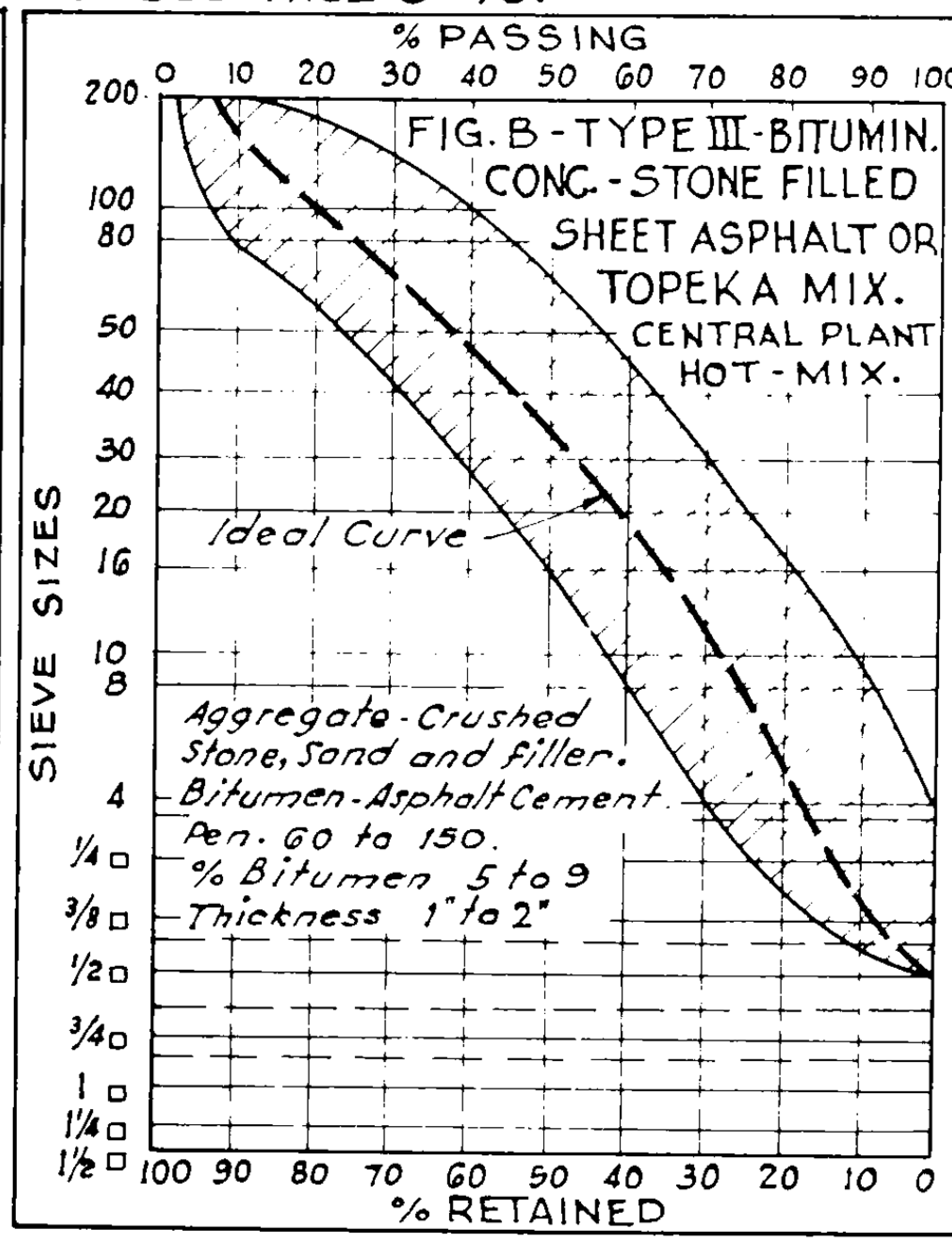


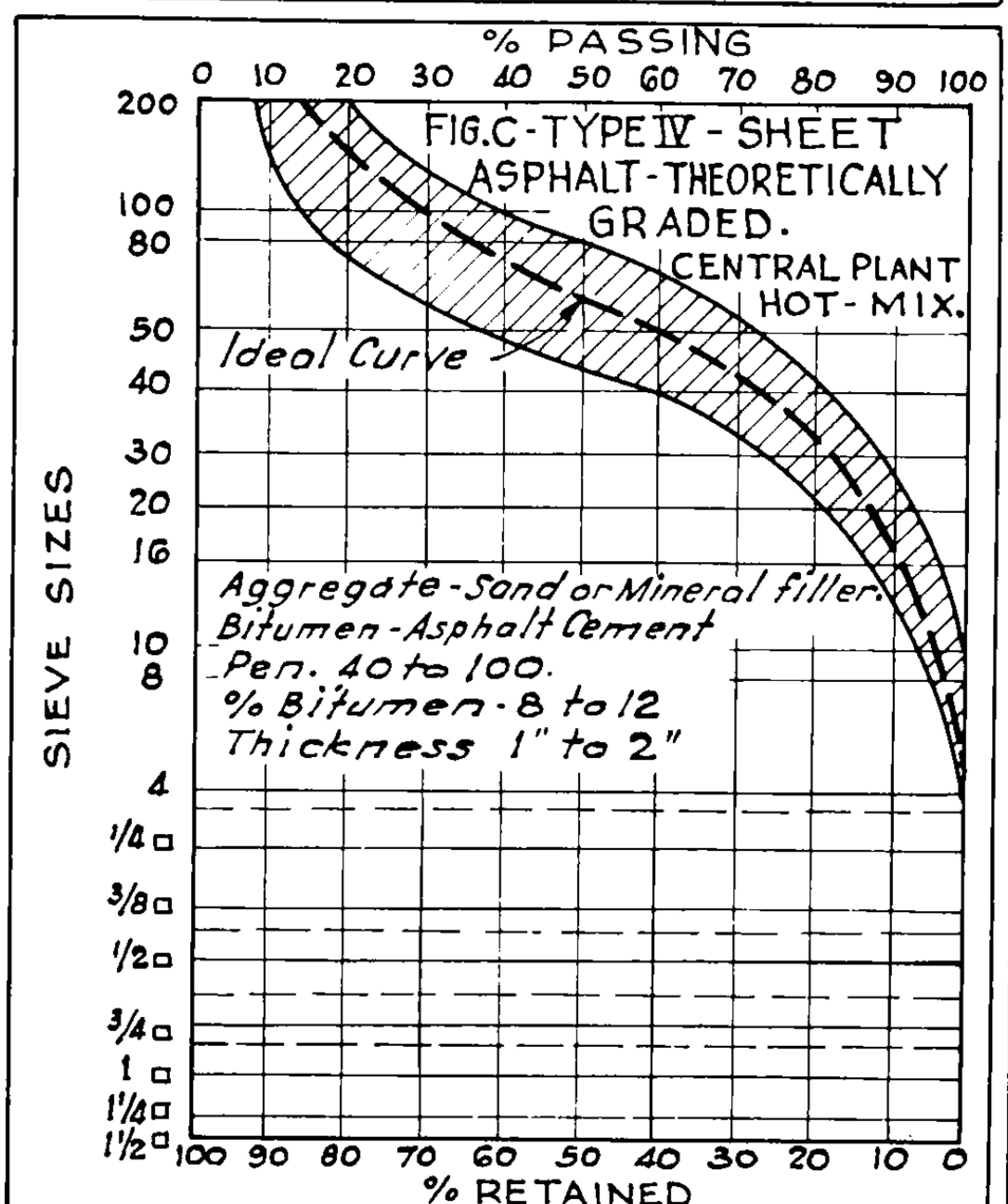
*Adapted from Bituminous Construction Handbook by Barber-Greene Co., Aurora, Ill.

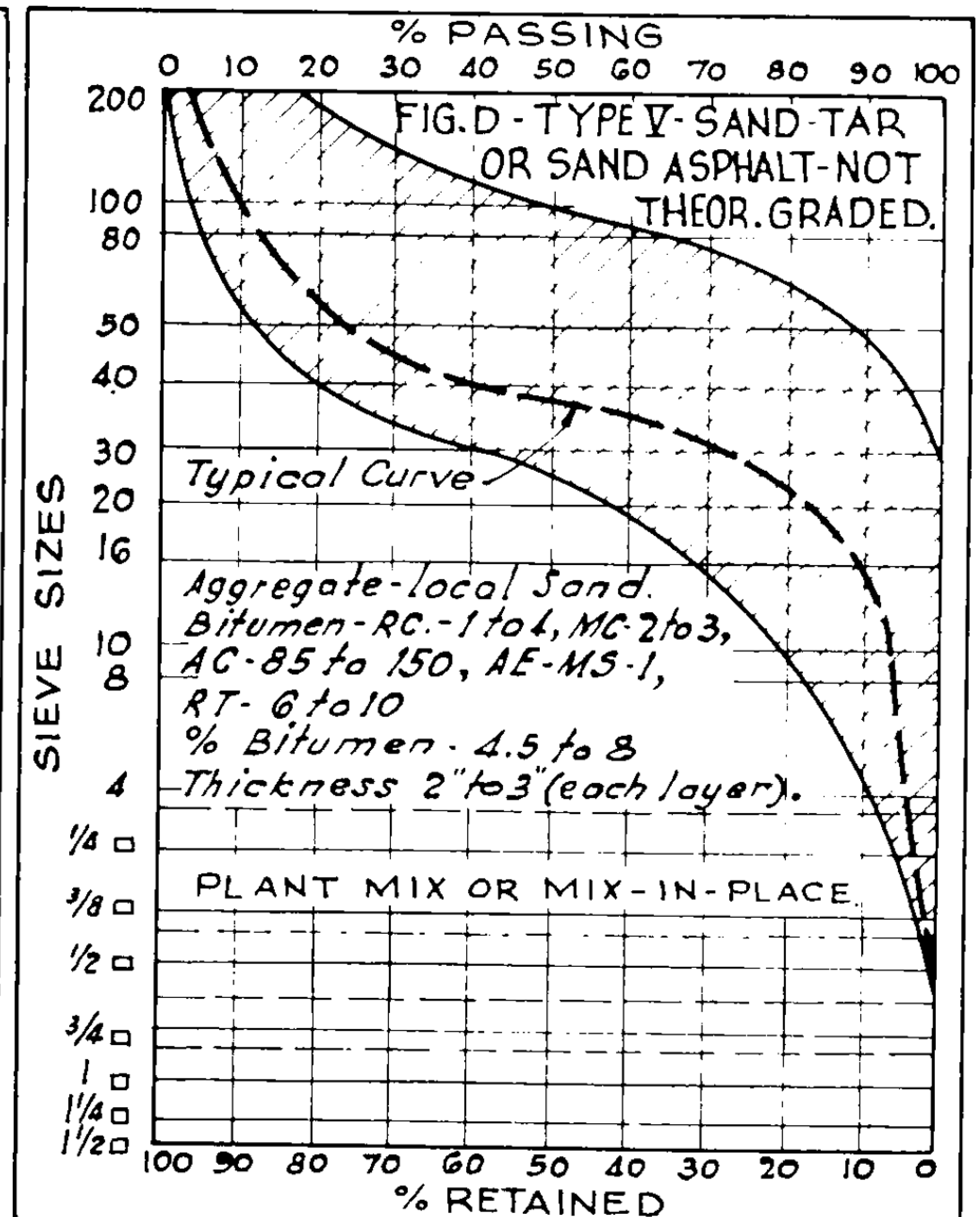
ROADS - BITUMINOUS MIXTURE DIAGRAMS-2*

FOR USE OF DIAGRAMS SEE PAGE 3-76.









* Adapted from Bituminous Construction Handbook by Barber-Greene Co., Aurora, Ill.

ROADS - USE OF BITUMINOUS MATERIALS† -1

ROADS - USE OF BITUMINOUS MATERIALS'

MATERIAL	ROAD TAR (RT) CUT-BACK ROAD TAR (RTCB)														ROAD OIL, SLOW CURING ASPHALTIC (SC)						
COMMERCIAL GRADE	RT-1	RT-2	RT-3	RT-4	RT-5	RT-6	RT-7	RT-8	RT-9	RT-10	RT-11	RT-12	RTCB 5	RTCB 6	SC-0	SC-1	SC-2	SC-3	SC-4	SC-5	SC-6
APPLICATION TEMPERATURE (F.)	60°-125°	60°-125°	80°-150°	80°-150°	80°-150°	80°-150°	150°-225°	150°-225°	150°-225°	175°-250°	175°-250°	175°-250°	60°-120°	60°-120°	50°-120°	125°-175°	120°-225°	160°-250°	175°-275°	225°-350°	300°-400°
Type I- Penet.Macadam (Hot)										x *	x *	x									x
Type I Penet.Macadam (Cold)				x	x	x															
Type I-Plant Mix- Open Graded Mixes							x *	x *	x *	x	x **	x **								x	x
Type I-Mix-in-Place Open Graded(crushed stone)					x *	x *	x *	x **	x **				x	x						x **	
Type II-Plant Mix Dense Graded Mixes							x	x	x	x	x	x						x	x	x	x
Type II-Mix-in-Place, Dense Graded Mixes (Gravel Mulch)				x *	x	x	x **	x **					x	x			x	x	x **		
Type III- Bitum. Concrete										x	x	x									
Surface Treatment		x	x	x	x	x	x	x	x	x	x		x	x		x	x	x	x	x	x
Seal Coats (Fog, Flush or Sand Cover)				x	x	x											x	x			
Seal Coats (Carpet, Stone,or Armour Coat)					x	x	x	x	x	x	x		x	x					x	x	x
Tack Coats				x	x	x	x	x	x	x											
Prime Coats (Dense or Tight Bases)	x *	x														x	x				
Prime Coats (Porous or Open Bases)		x *	x	x **													x				
Soil Stabilization	x	x	x	x	x	x															
Dust Palliative	x														x	x	x				
Patching Mixtures (Cold Patch)				x *	x *	x	x **	x **					x *	x			x *	x **	x **	x **	
Type V-Sand Tar: (Plant Mix)								x	x	x											
(Road Mix)						x	x	x **													
Crack and Joint Filler										x *	x	x		x							
	RT-1	RT-2	RT-3	RT-4	RT-5	RT-6	RT-7	RT-8	RT-9	RT-10	RT-11	RT-12	RTCB 5	RTCB 6	SC-0	SC-1	SC-2	SC-3	SC-4	SC-5	SC-6

†See pages 3-75, 3-76, and 3-77 for descriptions of Types I to V.

* Cool weather work (spring and fall). ** Hot weather work (summer).

<u>Note</u>: For both tars and road oils, the higher the number the more viscous the material. Thus an RT-1, RT-2, and SC-0 are non-viscous liquids at ordinary temperatures suited for soaking into a tightly bound base like clay-gravel. RT-4 to RT-7 and SC-2 to SC-4 will remain semi-liquid and are suited for mixing in place. RT-9 to RT-12 and SC-5 or SC-6 become solid or semi-solid at air temperatures and are suited for hot plant mixes, sealing, and macadam.

Ref: P. R. A., The Koppers Co., The Barrett Co., A.S.C.E., Barber-Greene Co.

ROADS - USE OF BITUMINOUS MATERIALS† - 2

ROADS - USE OF BITUMINOUS MATERIALS†

MATERIAL	MED. CURING CUT-BACK ASPHALT (MC)						RAPID CURING CUT-BACK ASPHALT (RC)						ASPHALT EMULSION (AE)				ASPHALT CEMENT (AC) Penetration				
COMMERCIAL GRADE	MC-0	MC-1	MC-2	MC-3	MC-4	MC-5	RC-0	RC-1	RC-2	RC-3	RC-4	RC-5	SS-1&2	MS-1	MS-2&3	RS-1	25 to 45	45 to 70	70 to 85	85 to 150	150 to 200
APPLICATION TEMPERATURE (F.)	60° 150°	80° 175°	150° 200°	175° 225°	175° 250°	200° 275°	60° 125°	60° 150°	125° 175°	150° 200°	175° 225°	200° 250°	50° 120°	60° 120°	60° 120°	80° 135°	275° 350°	250° 350°	250° 350°	250° 350°	250° 400°
Type I-Penetration Macadam (Hot)											x	x									
(Cold)																x			x**	x	x *
Type I-Plant Mix Open Graded					x	x				x	x	x			x						x
Type I-Mix-in-Place Open Graded (Crushed Stone)				x	x				x	x	x			x							
Type II-Plant Mix Dense Graded				x	x	x				x	x	x	x		x					x	x
Type II-Mix-in-Place Dense Graded (Mulch)			x	x	x **								x								
Type III-Bituminous (Asphaltic) Concrete																		x	x	x	x *
Type IV-Sheet Asphalt																		x	x		
Type V-Sand Asphalt Plant Mix			x	x					x	x	x								x	x	
Type V-Sand Asphalt Mix-in-Place (Road Mix)				x				x	x					x							
Surface Treatment		x	x	x	x	x		x	x	x	x	x		x		x				x	x
Seal Coats (Fog, Flush, or Sand Cover)	x	x	x	x			x	x	x							x					x
Seal Coats (Carpet, Stone, or Armour Coat)			x	x	x	x			x	x	x	x		x		x			x	x	x
Tack Coats			x	x				x	x	x	x					x					x
Prime Coats-Dense or Tight Bases	x *	x **											x								
Prime Coats-Open or Porous Bases		x	x										x	x		x					
Soil Stabilization			x						x				x								
Dust Palliative	x	x					x						x								
Patching Mixtures (Cold Patch)			x	x	x			x	x	x					x						
Joint Filler-Brick																	x				
Crack and Joint Filler											x	x						x	x	x	

†See pages 3-75, 3-76, and 3-77 for descriptions of Types I to V.

*Cool weather work (spring and fall). **Hot weather work (summer).

NOTE: For cut-back asphalts, the higher the number the more viscous the material. For asphalt cements, the higher the penetration number the softer the asphalt; thus for heavy traffic in hot weather a stiff grade such as 45 to 70 or 70 to 85 is used and for cool weather or light traffic softer grades are used. For asphalt emulsions: SS = Slow setting; MS = medium setting; RS = rapid setting.

Ref.: P.R.A., Asphalt Institute, A.S.C.E., Barber-Greene Co., Texas Co.

ROADS - DESIGN OF RIGID PAVEMENTS

DESIGN OF SLAB THICKNESS BY SHEETS' EMPIRICAL FORMULAS*

For stresses and thickness of plain or reinforced concrete and cement bound macadam.

Case I - Corners protected by adequate load transfer at joints and cracks such as shown on Page 3-81 for unreinforced slabs and Page 3-82 for reinforced slabs.

Formulas: $d_1 = \sqrt{\dfrac{1.92\,Wc}{S}}$; $t_i = 0.85 d_1$; $t_e = 1.5 t_i$
$t_i = 2/3\, t_e$; $t_e = 1.275\, d_1$

For 2'-6" edge slope $t_e = 1.43 t_i$; for 3'-0" edge slope $t_e = 1.33 t_i$

Case II - Corners unprotected, no adequate load transfer at joints and cracks. Space contraction and warping joints at 15'-25' centers and expansion joints at 90' to 120' centers. Slab thickness at free transverse joints to be t_e and sloped back 5' to 10' for thickened edge designs.

Formulas: $d_2 = \sqrt{\dfrac{2.4\,Wc}{S}}$; $t_i = 0.85 d_1$; $t_e = \dfrac{d_2 - 0.47 t_i}{0.53}$

NOTE: When subgrade support is uncertain - slab may be checked by cantilever formula: $t_e = \sqrt{3W \div S}$; $t_i = \sqrt{1.5W \div S}$

Where: W = Moving wheel load in pounds. Factors 1.92 and 2.4 include allowance for impact factor of 1.20; for other impact factors multiply 1.92 or 2.4 x $\dfrac{\text{impact factor}}{1.20}$

c = Coefficient of subgrade support, see Table "D"

$S = \dfrac{\text{Modulus of rupture or "Flexural Strength" of concrete}}{\text{Factor of Safety.}}$

Recommended value of "S" = ½ Modulus of rupture. Usually varies in highway practice from 300 to 375 pounds per sq. in.

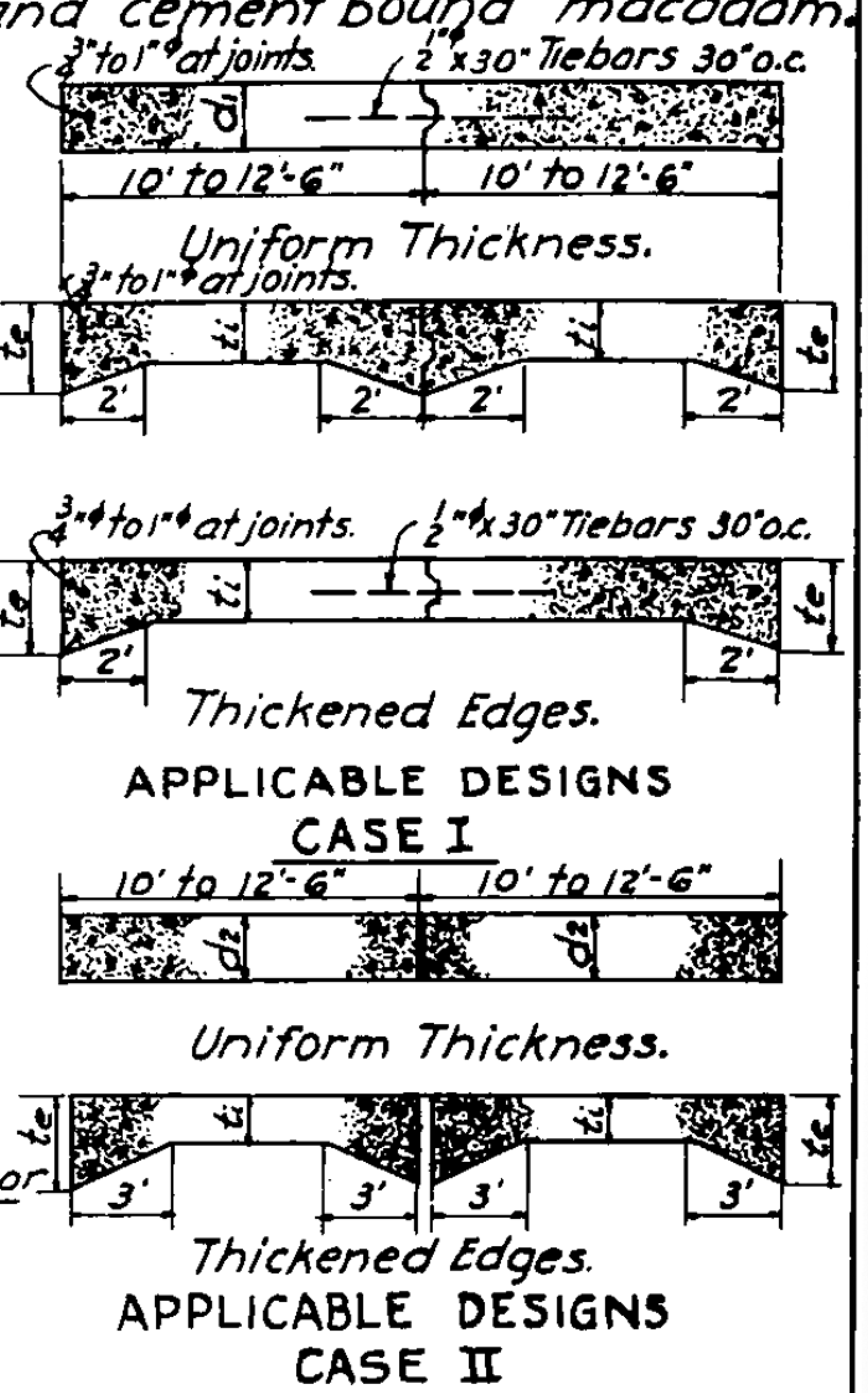
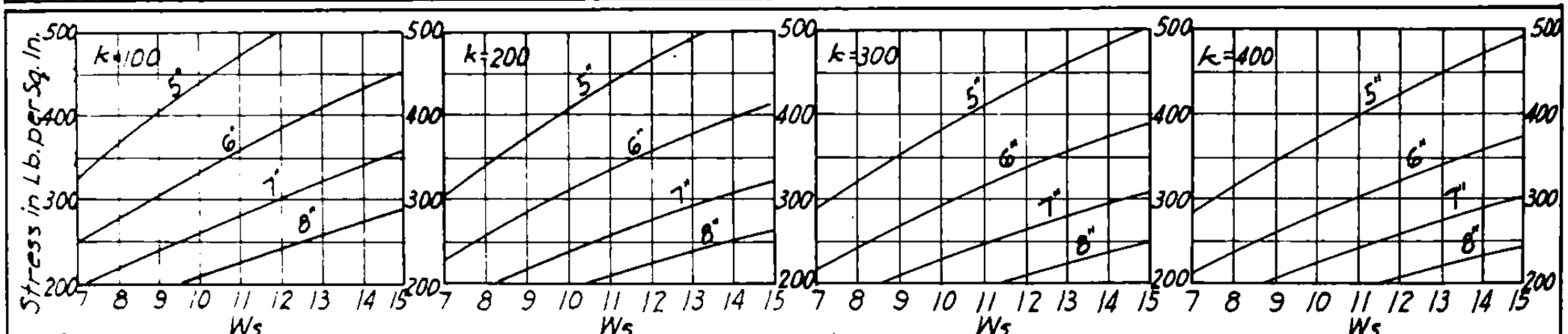


FIG. A - DESIGN SECTIONS.



Stresses are for average concrete and normal tire pressures. Where Ws = Gross Wheel Load in thousands of pounds (Static wheel load plus any impact) applied at slab interior, i.e., 2 to 3 feet from any edge. The edge and corner stresses will approximate the interior in slabs with edges "te" thickened from 1.33 to 1.6 of "ti" and sloped 2' to 3', and with joints and reinforcing designed as shown on Pages 3-81; 82.

k = Modulus of subgrade reaction in lb. per sq. in. for settlement of one inch based on 0.1" or 0.05" settlement of 30" dia. rigid circular bearing plate. "k" should preferably be determined by actual test with subgrade in weakened condition, i.e., saturated or frost coming out.

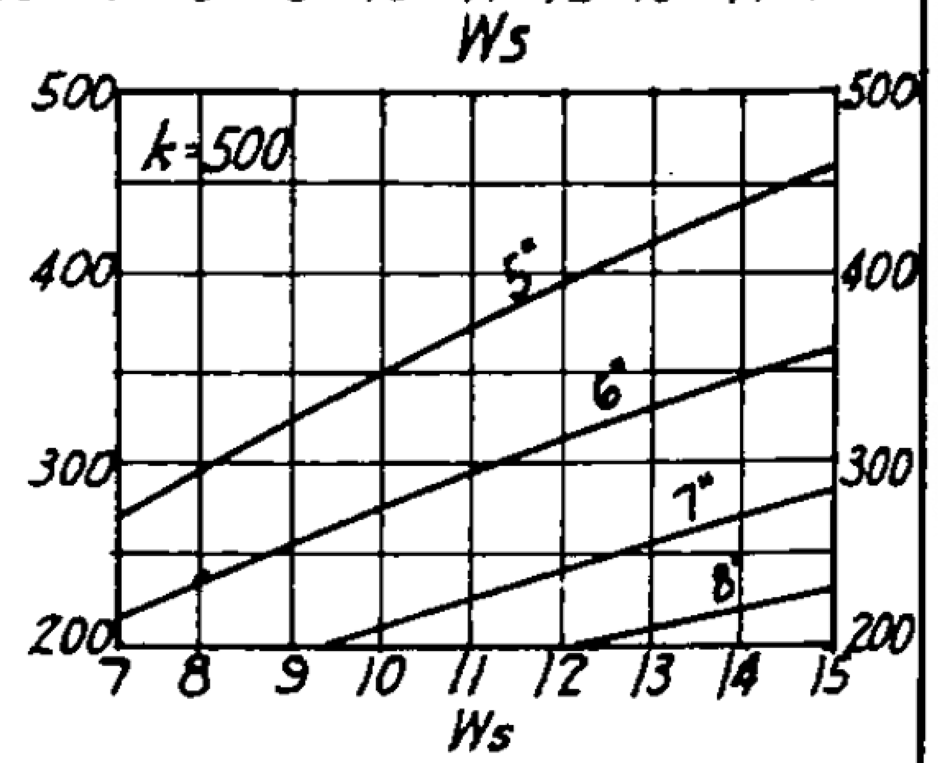


FIG. B - STRESSES IN SLABS OF 5", 6", 7" & 8" THICKNESS (BY WESTERGAARD'S ANALYSIS).

TABLE C - RECOMMENDED THICKENED EDGE DESIGNS.*
7"- 4.7"- 7" , 2' Slope.
7½"- 5"- 7½", 2' Slope.
8"- 5½"- 8" , 2' Slope.
9"- 6"- 9" , 2' Slope.
10"- 6.7"- 10", 2' Slope.
10"- 7"- 10", 2'-6" Slope.

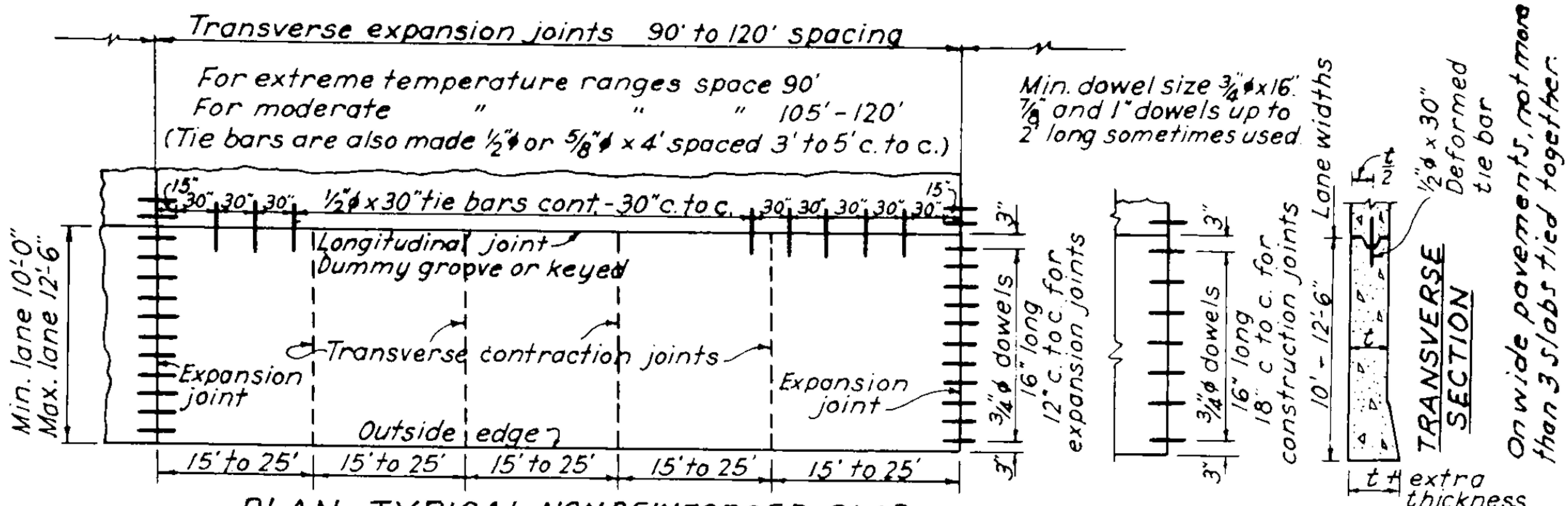
TABLE D - RELATION OF SOIL, SUB GRADE, BEARING VALUE & CONSTANTS "c" & "k".

Soil	Subgrade	Bearing Value †	Value of "k"	Value of "c"	Approx. C.B.R.
Clay & Silt	Soft & Plastic	10 lb. per sq. in.	100	1.000	3 to 10
Sand Clay, Poor Gravel.	Fairly Hard	20 lb. per sq. in.	200	0.900	10 to 25
Sand, Sand Clay, Gravel.	Hard	30 lb. per sq. in.	300	0.842	20 to 35
Gravel.	Very Hard	40 lb. per sq. in.	400	0.800	35 to 50
Good Gravel.	Extremely Hard	50 lb. per sq. in.	500	0.770	50 to 80

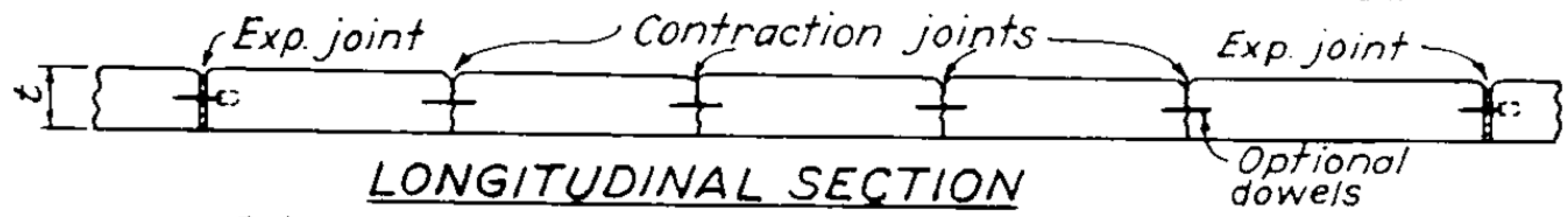
† Where sub grade bearing value = lb. per sq. in. on circular plate 30" to 36" dia. causing settlement of 0.1".

*From Concrete Road Design by Frank T. Sheets. Ref.: Structural Design of Concrete Pavements by Teller & Sutherland. Reinforced Concrete Pavements by R.O. Bradbury; Stresses in Concrete Runways by H.M. Westergaard.

ROADS - CONCRETE PAVEMENT DETAILS - 1

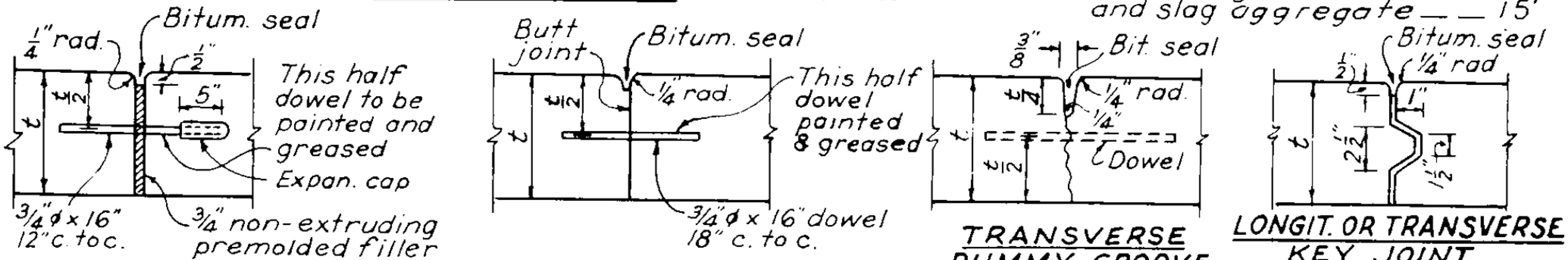


PLAN-TYPICAL NONREINFORCED SLAB



LONGITUDINAL SECTION

CONTRACTION JOINT SPACING
Crushed granite aggregate 25'
Limestone & calcareous gravel aggregate ___ 20'
Siliceous gravel and slag aggregate ___ 15'



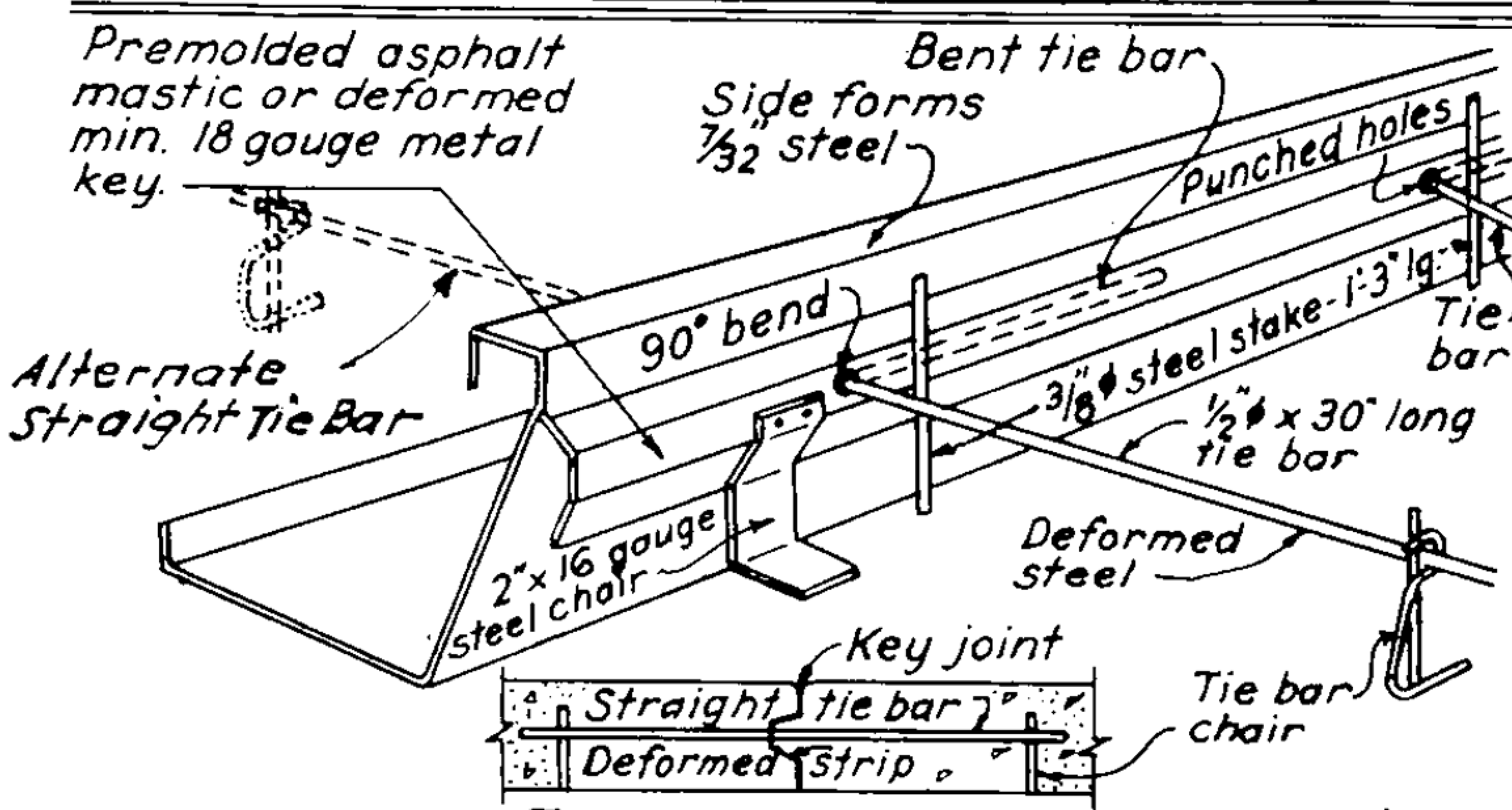
TRANSVERSE EXPANSION JOINT

TRANSVERSE DOWELED CONSTRUCTION JOINT

TRANSVERSE DUMMY GROOVE CONTRACTION JOINT
Dowels ¾" x 16" - 12" c. to c. Required by P.R.A. for A-4 to A-7 subgrades.

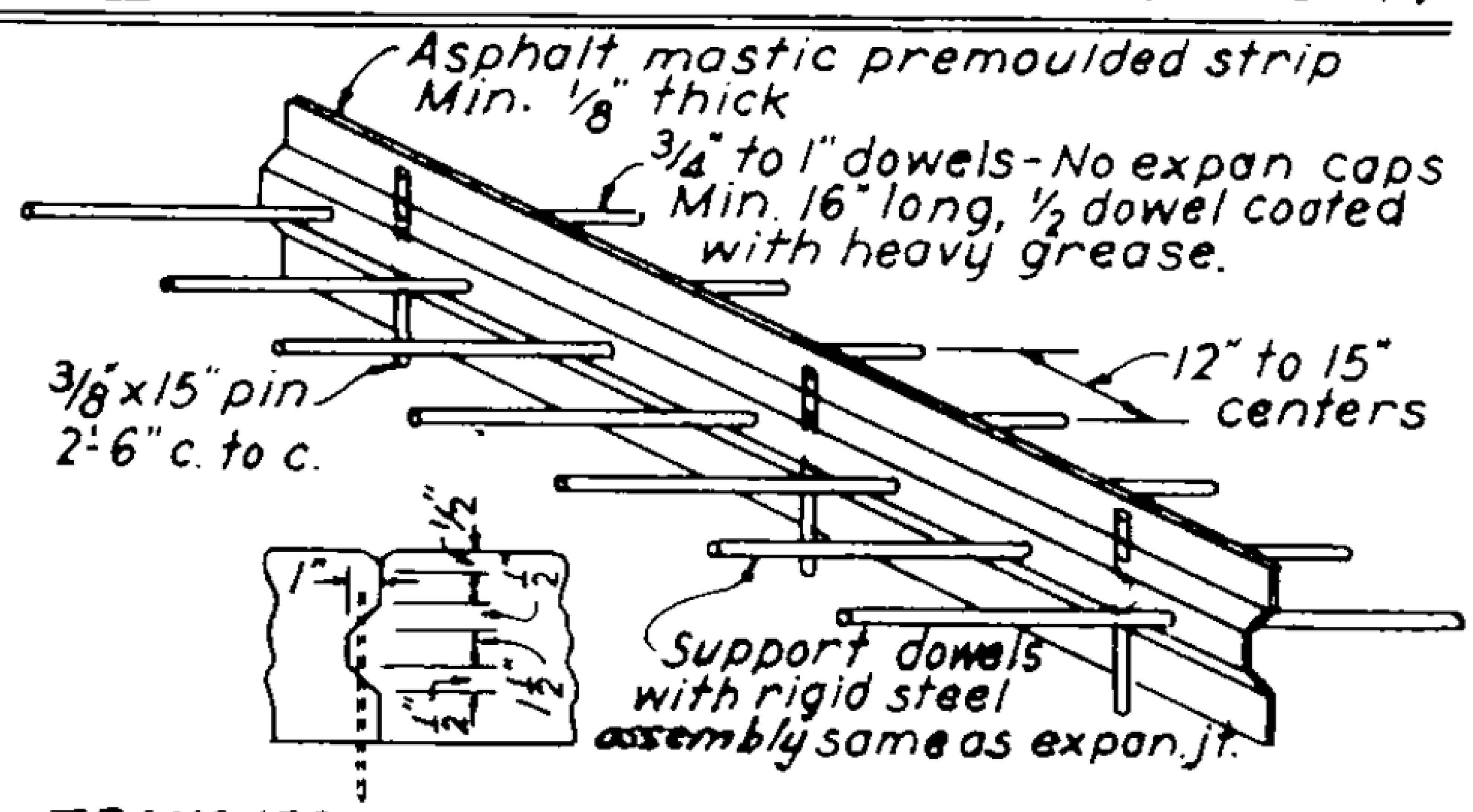
LONGIT. OR TRANSVERSE KEY JOINT
With premoulded mastic or deformed metal - to be left in concrete.

JOINT LOCATION & DETAILS* (No interior slab reinforcement)

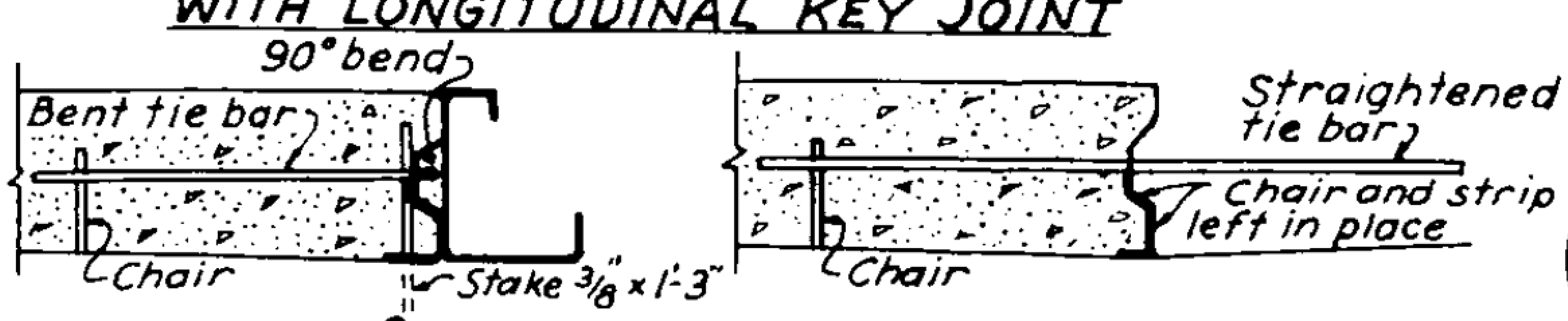


·TWO-LANE PLACING

STEPS IN THE CONSTRUCTION OF PAVEMENT WITH LONGITUDINAL KEY JOINT



TRANSVERSE CONTRACTION JOINT ASSEMBLY



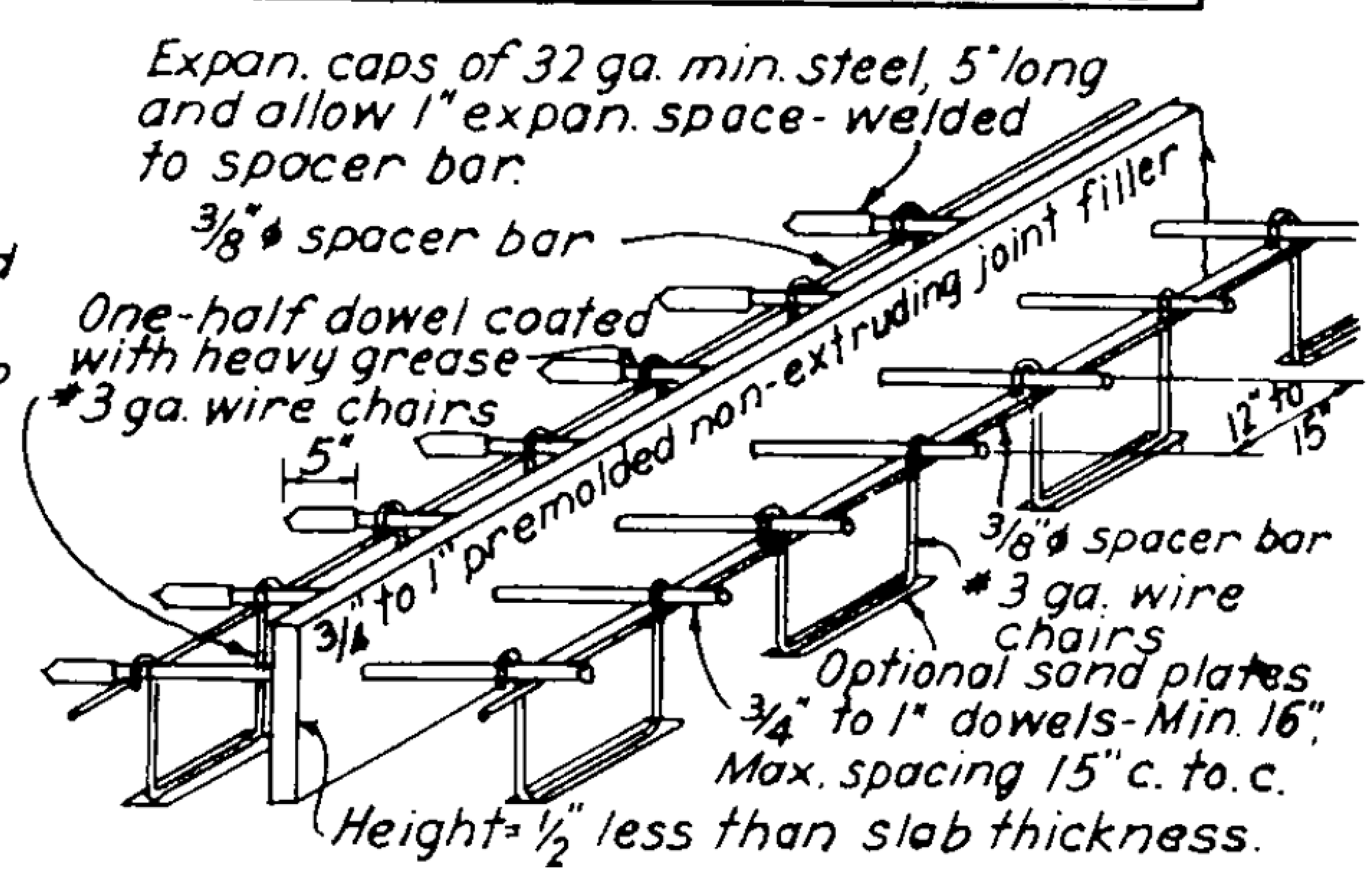
ONE-LANE PLACING

Step 1.- Keyed joint in place against side form

Step 2.- Side form removed and tie bars straightened for adjacent lane.

LONGITUDINAL KEY JOINT ASSEMBLIES†

Two-lane placing-use straight tie bars inserted through deformed strip held by pins and chairs.
One-lane placing-use bent tie bar assembly as detailed.

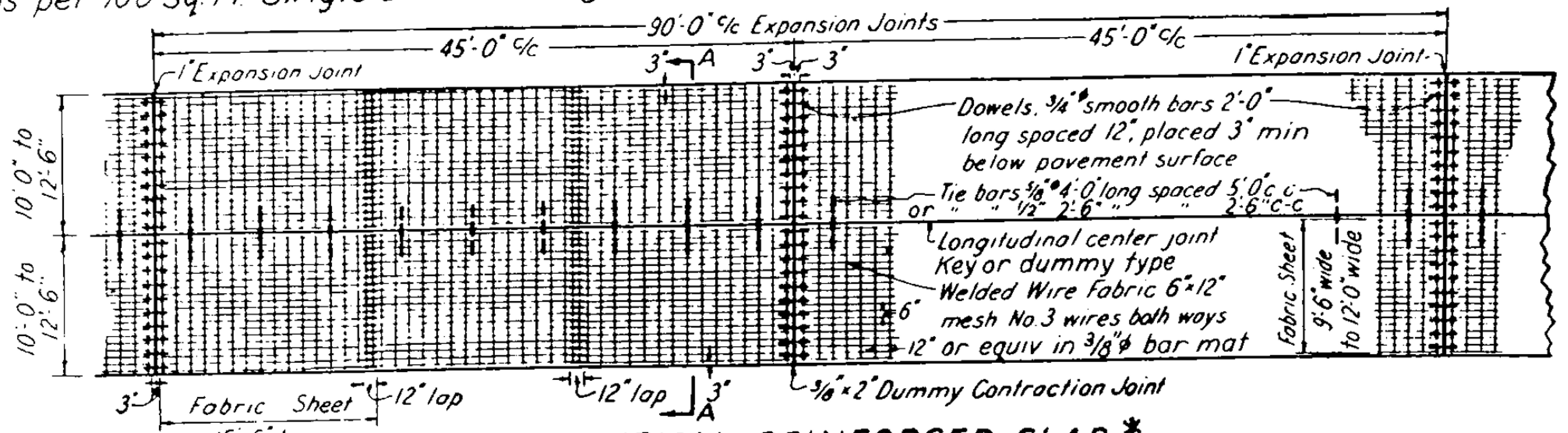


TRANSVERSE EXPANSION JOINT ASSEMBLY†

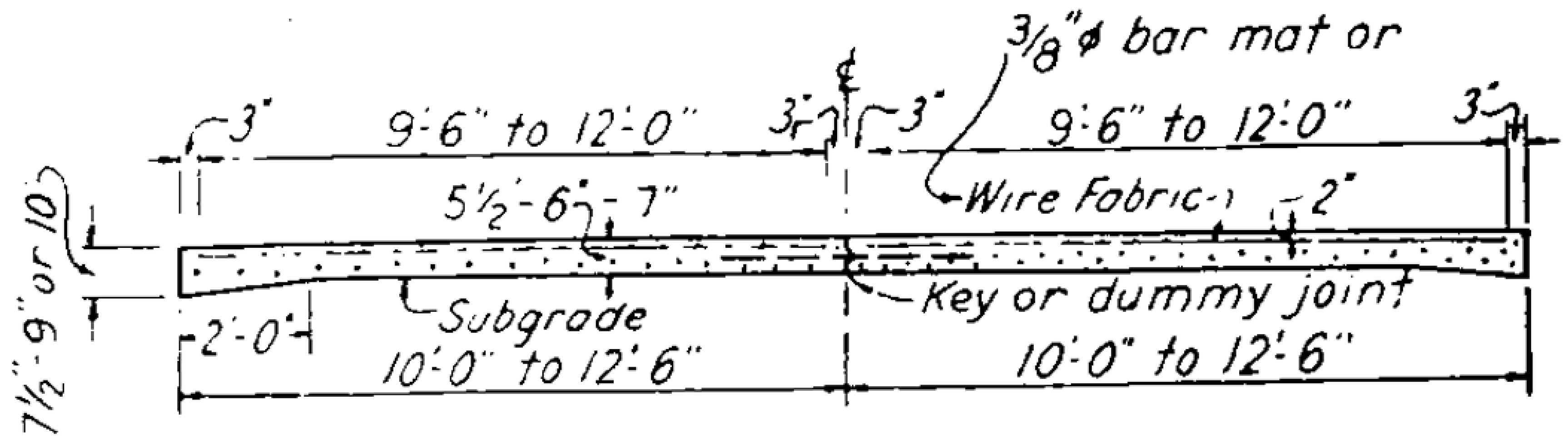
†Assembly details from LaClede Steel Co.
*In accordance with recommendations of P.C.A., P.R.A., A.A.S.H.O., C.A.A. and U.S.E.D.

ROADS-CONCRETE PAVEMENT DETAILS-2

NOTE: Expansion joints commonly spaced from 90'-0" to 120'-0"; contraction joints 30'-0" to 50'-0". Min. reinforcement is #6 wire on 6"x 12" centers. Wire mesh fabric should total 40 to 65 lbs per 100 sq. ft. Single bar mats 3/8"ϕ & 1/4"ϕ bars to total 50-65 lbs. per 100 sq. ft. may be used.

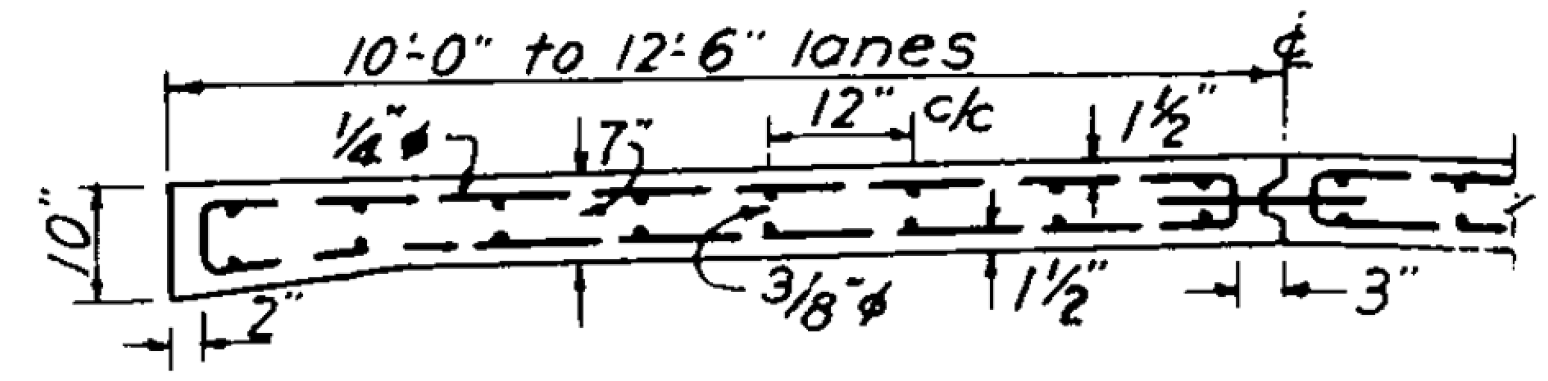


PLAN TYPICAL REINFORCED SLAB *



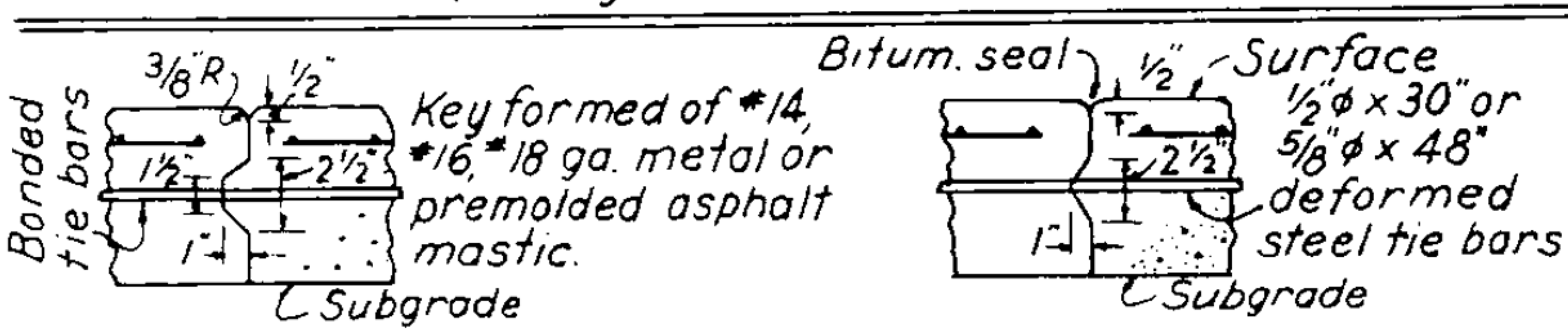
TRANSVERSE SECTION A-A

Showing location of single bar mat or wire fabric. Adequate for all usually encountered conditions when sizes and spacing shown in plan are used.

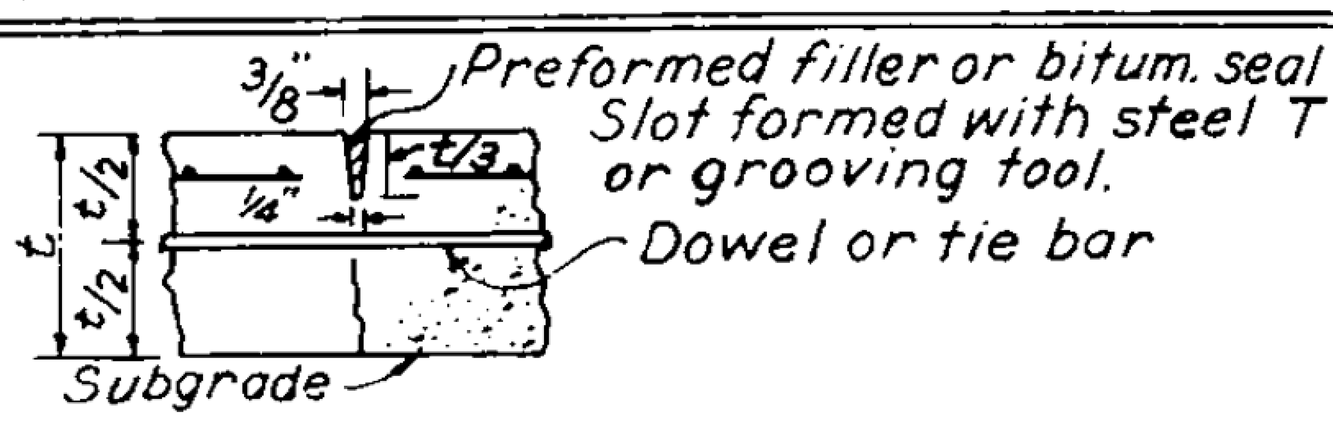


TRANSVERSE SECTION

Showing double bar mat 1/4"ϕ transverse bars at 20" c/c and 3/8"ϕ longit. bars at 12" c/c. Used for bridge approaches, extreme frost conditions, bad subgrades and over culverts. Use at least 100# per 100 sq. ft. of slab of 3/8"ϕ bars.

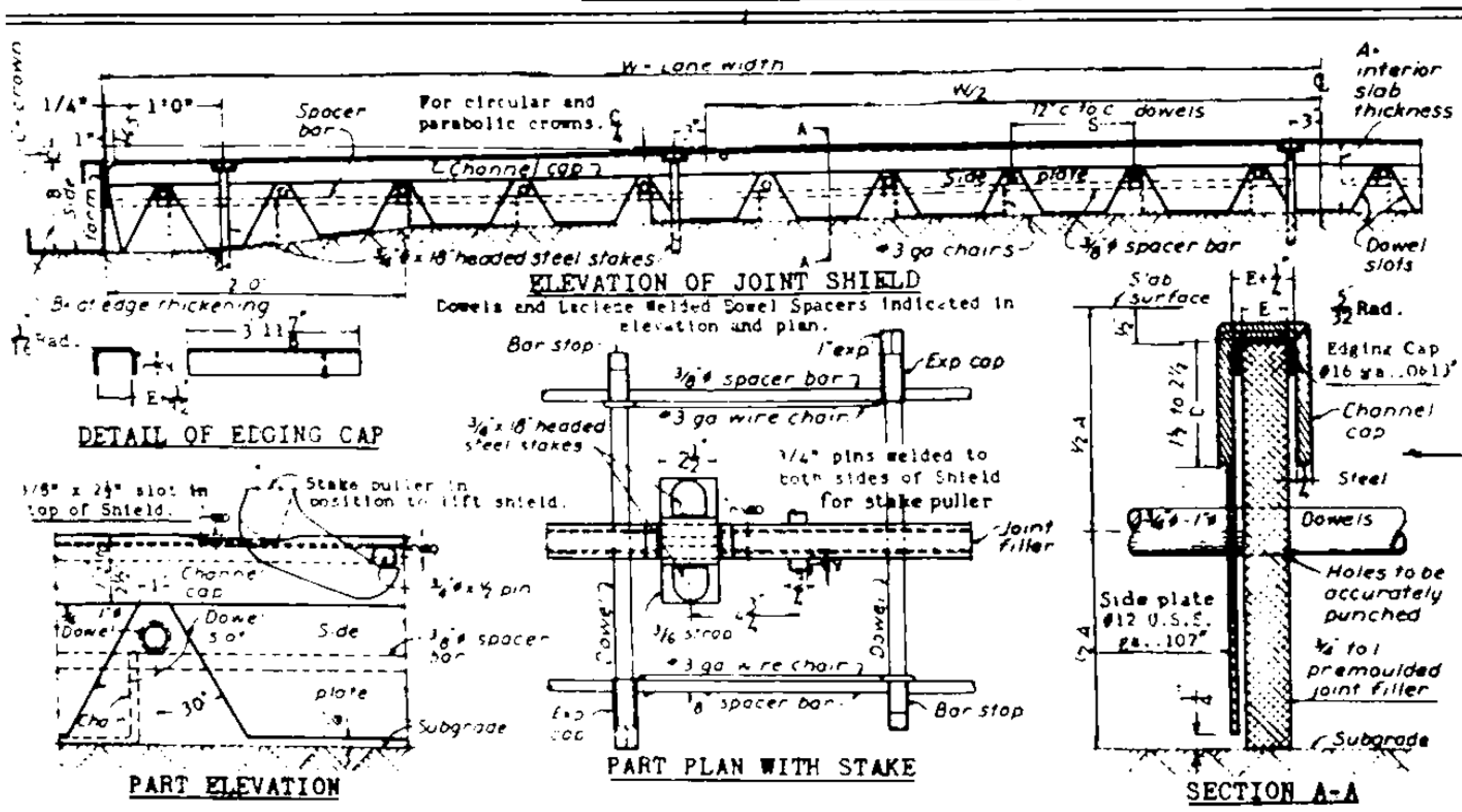


PREFORMED LONGITUDINAL JOINTS

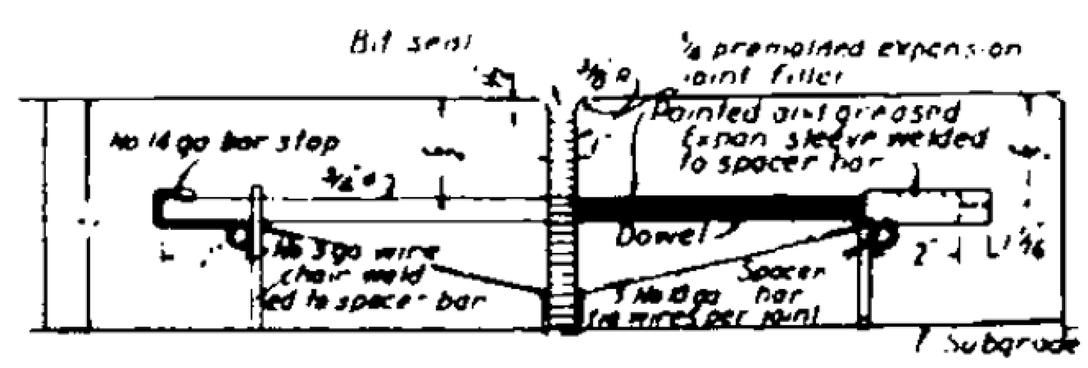


DUMMY GROOVE

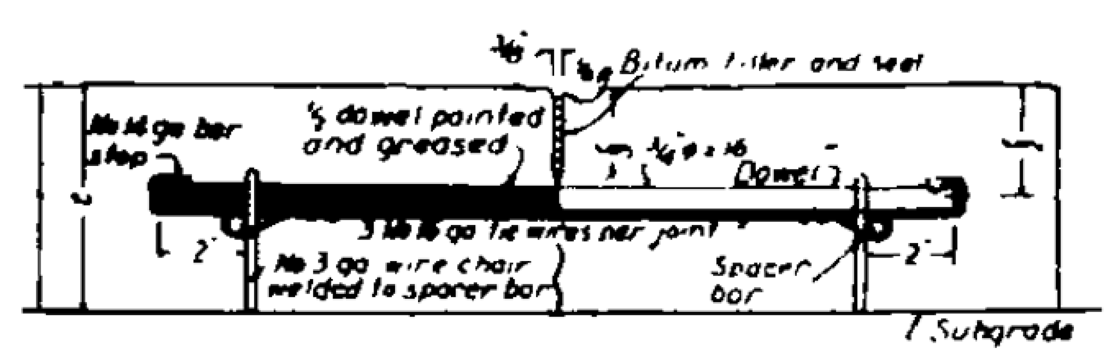
TYPES OF JOINTS **



HEAVY JOINT SHIELD FOR TRANSVERSE EXPANSION JOINTS ***



TRANSVERSE DOWELED EXPANSION JOINT ASSEMBLY IN PLACE *** (Installing shield at left)



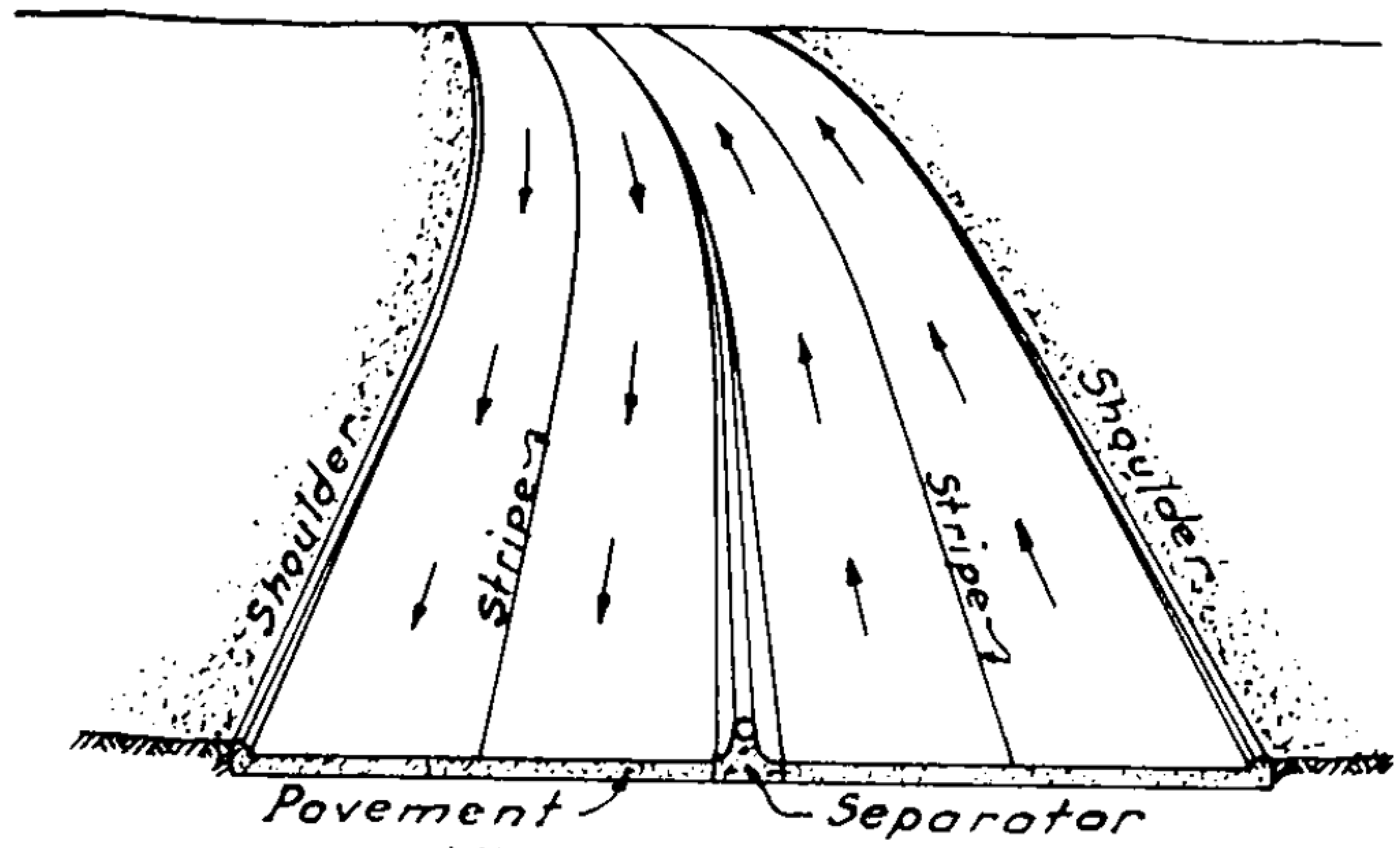
TRANSVERSE DOWELED CONTRACTION JOINT ASSEMBLY IN PLACE ***

The shield is removed before final screeding by pulling the 3/4"ϕ stakes and lifting the shield with the stake puller as shown. The edging cap is removed after the joint has been edged.

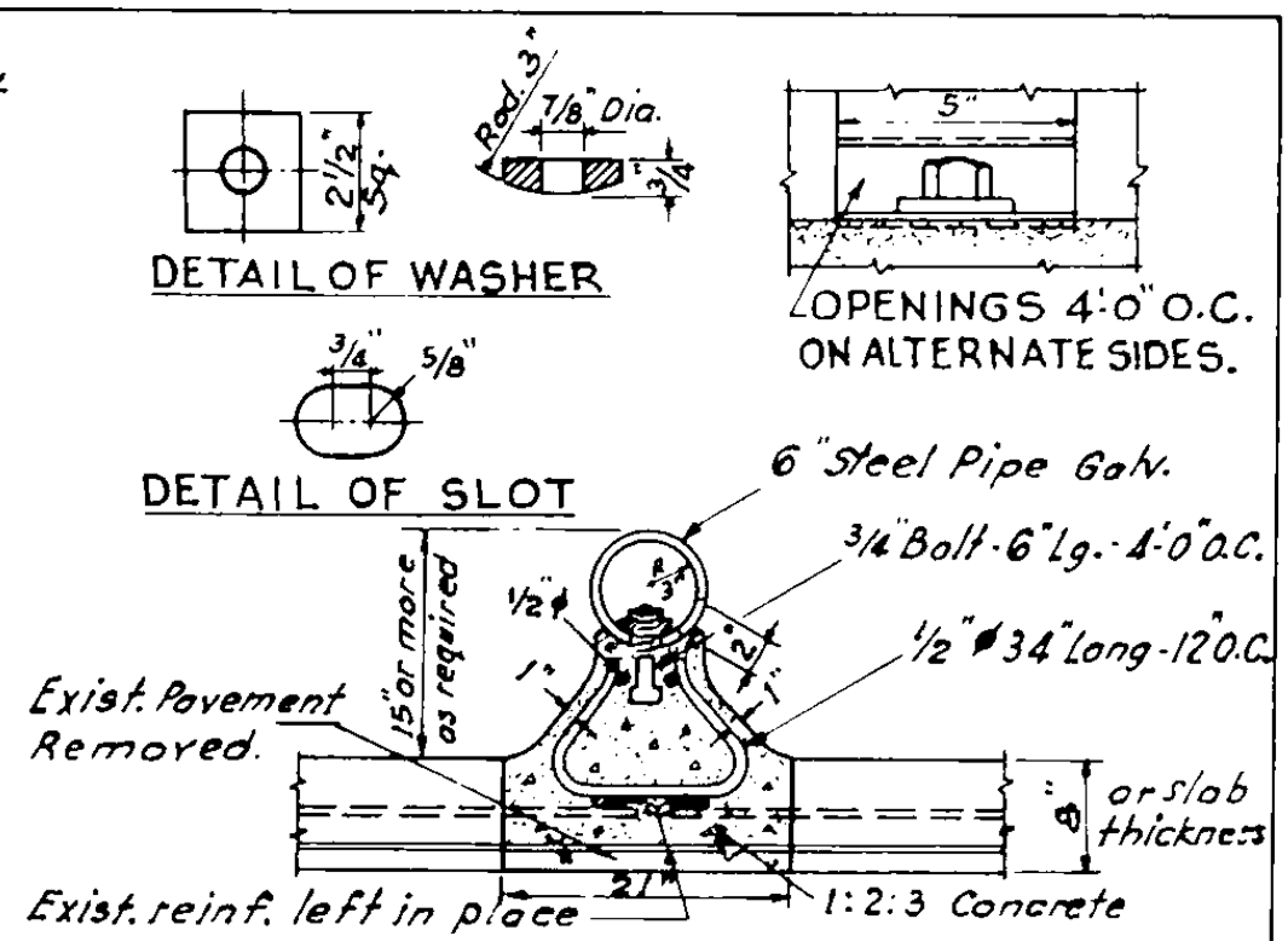
* Adapted from Bradbury, Reinforced Concrete Pavements, Wire Reinforcement Institute Wash., D.C. ** From P.R.A.
*** From Laclede Steel Company.

ROADS - TRAFFIC SEPARATORS & MEDIAN STRIPS

Used for urban express highway with high speeds & limited access to prevent vehicles from crossing median zone.



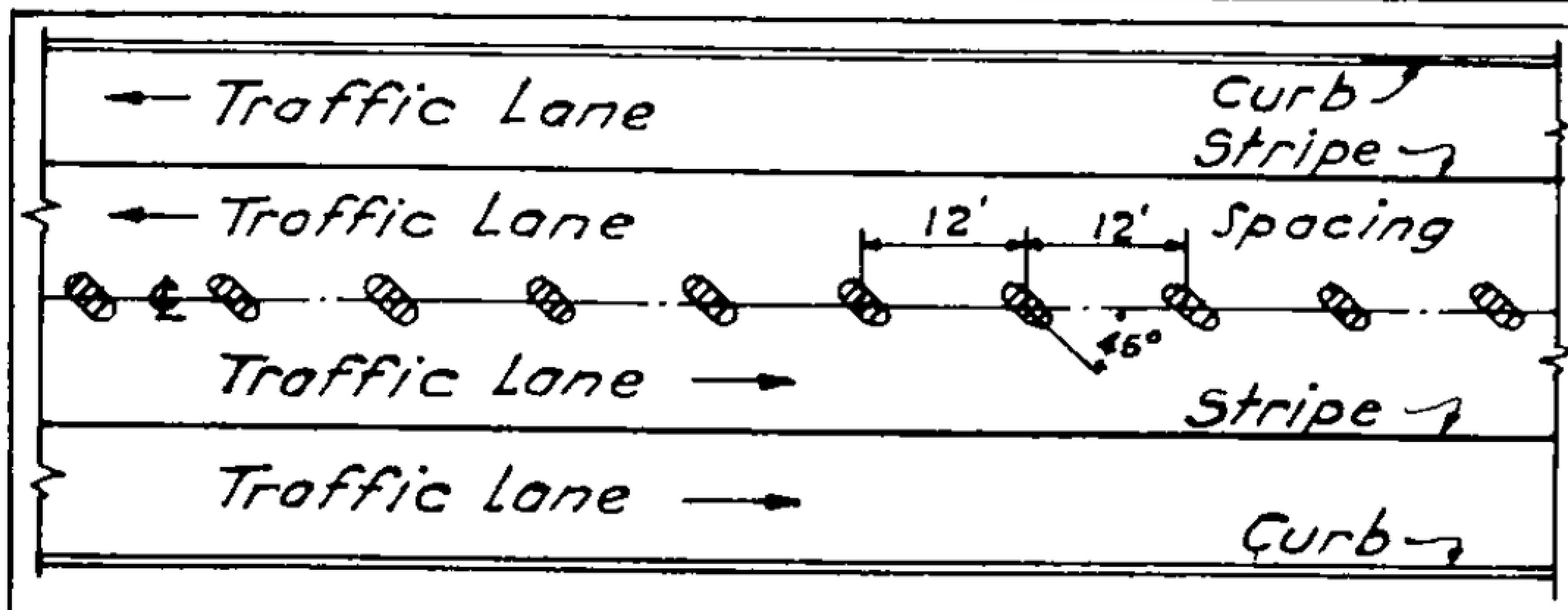
VIEW OF HIGHWAY



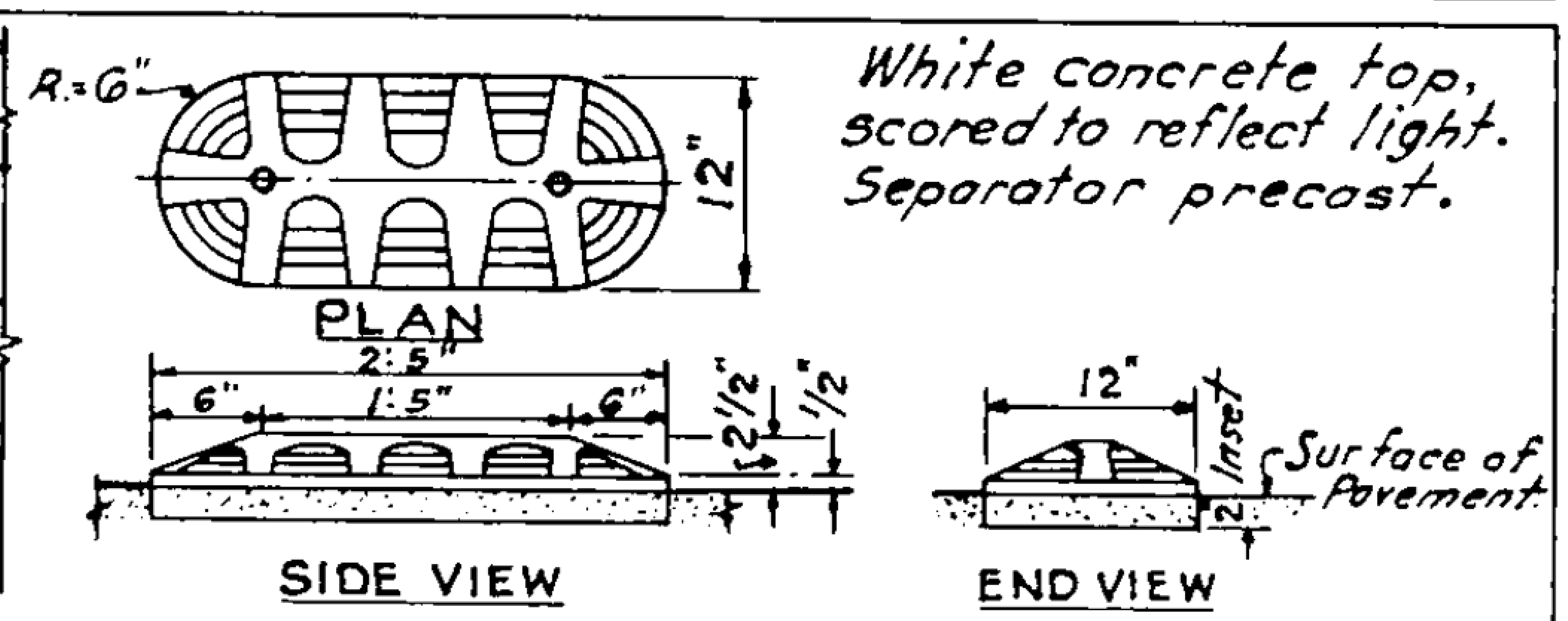
CROSS SECTION

FIG. A - NON-MOUNTABLE SEPARATOR.*

For dividing traffic on highways and streets where Right of Way is limited.



PLAN OF STREET



DETAILS

FIG. B - CROSSABLE SEPARATORS.**

For existing streets with limited Right of Way where frequent crossing of median zone is necessary. Omit at major intersections.

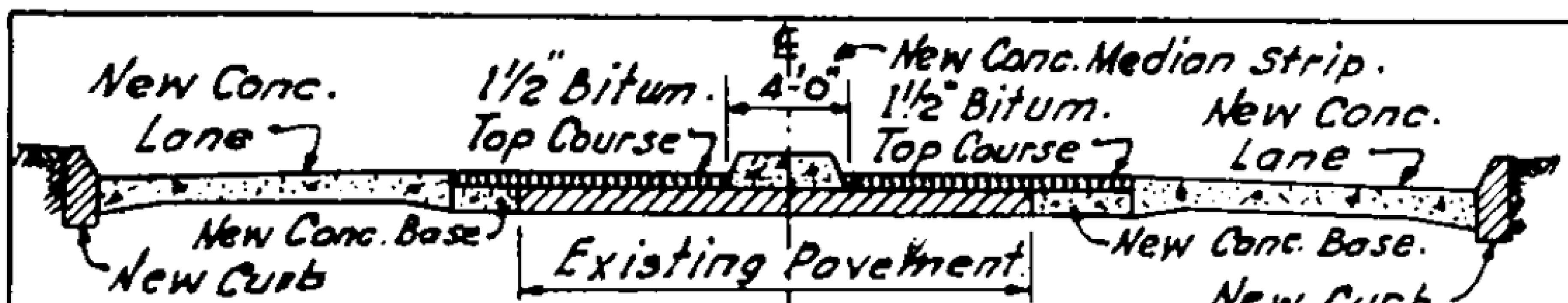


FIG. C - MEDIAN STRIP & WIDENING EXISTING NARROW STREET OR ROAD.***

Construct new concrete lanes first to allow traffic flow during reconstruction of inner lanes.

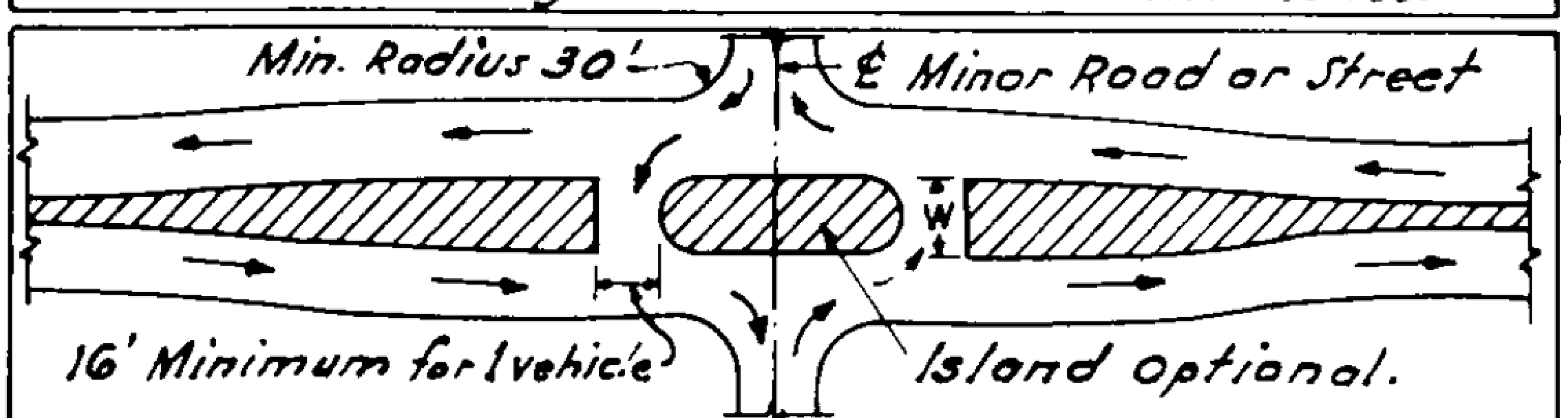
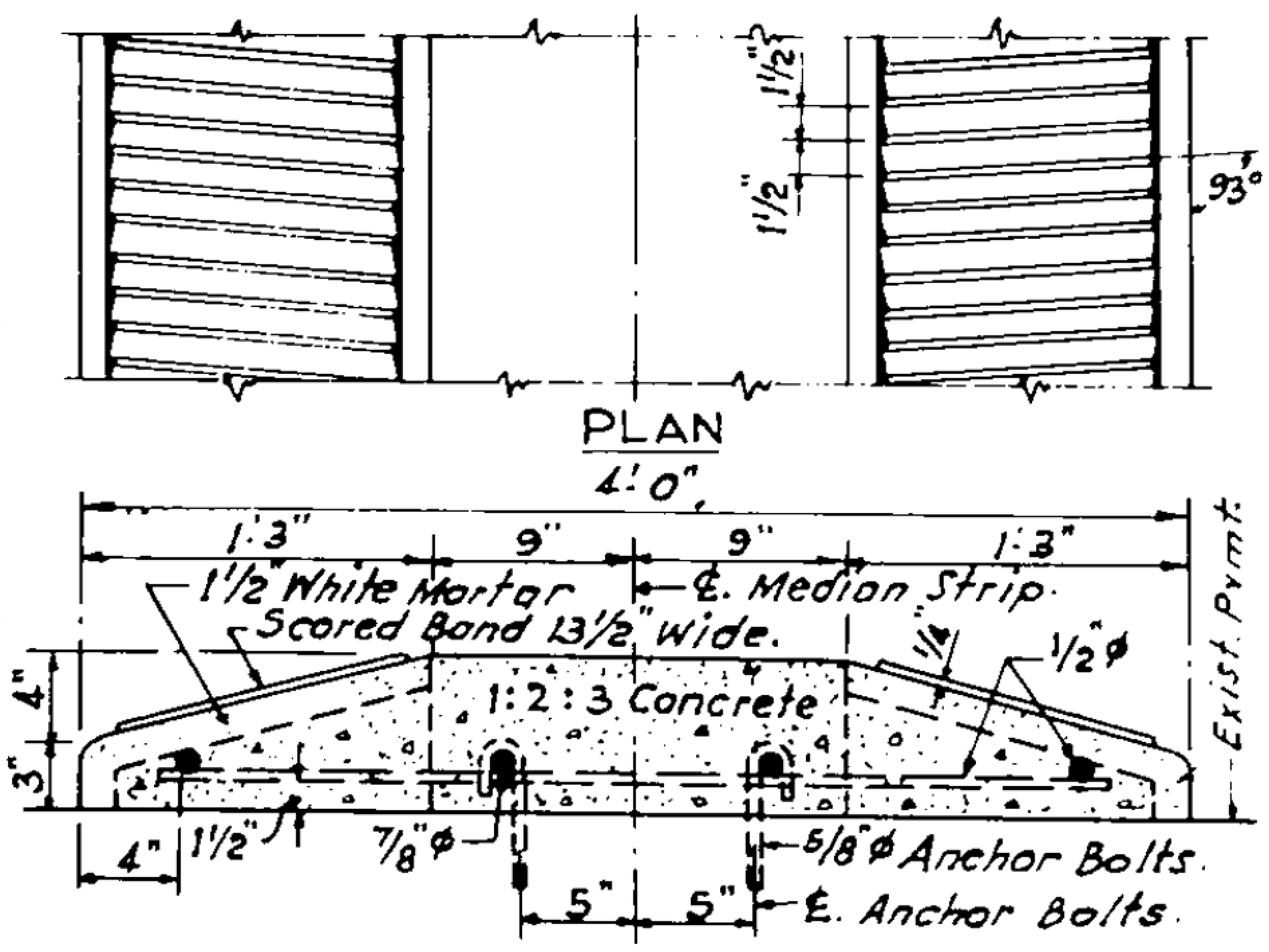


FIG. D - MEDIAN WIDTH AT CROSSINGS.†

Where left turns, U-turns and crossings are allowed on divided streets or highways, the median strip should be widened to a minimum "W" of 19' for "P" traffic and 30' for "T" or "M" traffic.



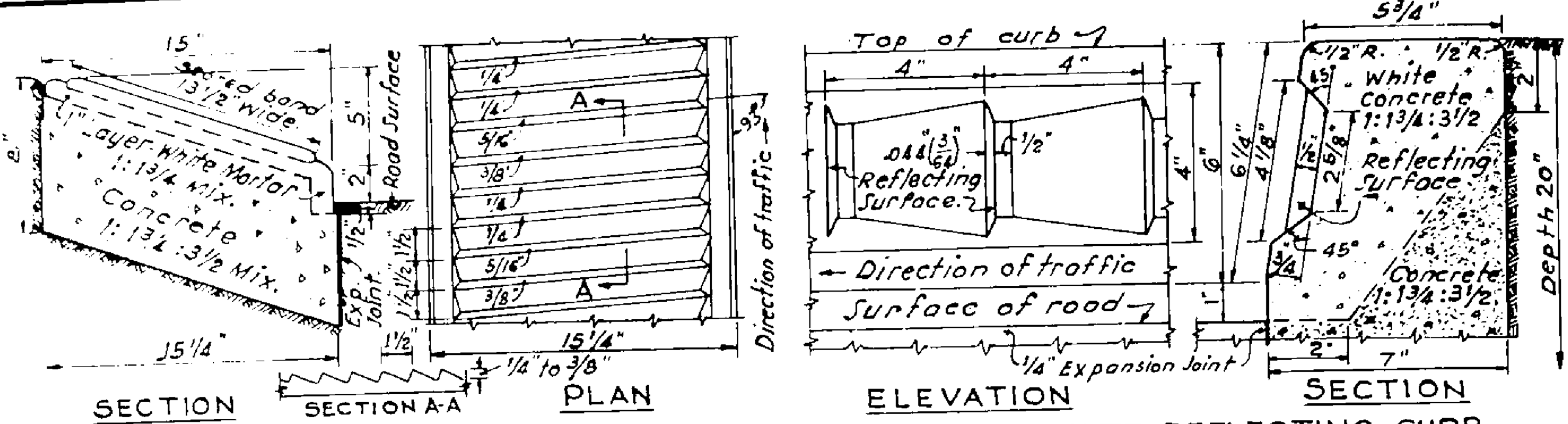
CROSS SECTION

FIG. E - REFLECTING MEDIAN STRIP.††

4' all paved type - Use at structures and in urban areas where clear width or Right of Way is limited.

*Adapted from New York State Div. of Highways. **Adapted from Eng. News Record-Jan. 27, '44, by R N Ricketts. ***Public Roads Admin. †Adapted from Amer. Assoc. of State Highway Officials. ††Adapted from Portland Cem. Assoc.

ROADS - CURBS, GUTTERS & SIDEWALKS



SLOPING SCORED FINISH CURB. VERTICAL WHITE REFLECTING CURB.

FIG. A - SIMPLIFIED WHITE REFLECTING CURBS.*

Vertical Barrier type can be cast in place against built up wood forms and is used at intersections, parking areas, bridges, traffic circles, underpasses, shoulders and adjacent to sidewalks. Sloping surmountable type is cast in place and hand scored while still plastic with scoring tool. Used for flanking center islands, traffic circles, median strips and traffic separators. Install 1/2" premolded non-extruding expansion joint filler transversely at 20' spacing, both types. White Concrete made from white Cement & light colored aggregate.

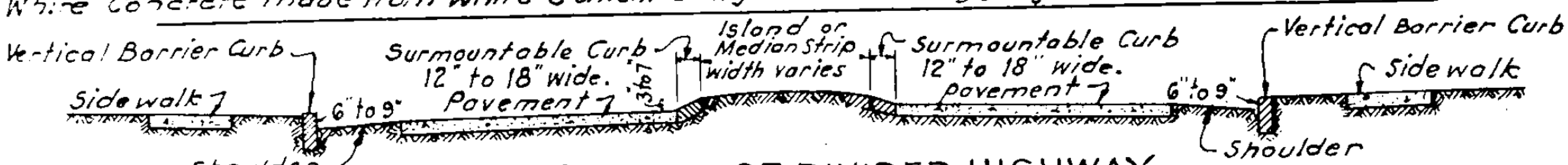


FIG. B - SECTION OF DIVIDED HIGHWAY.

Showing effective use of surmountable and barrier curbing.

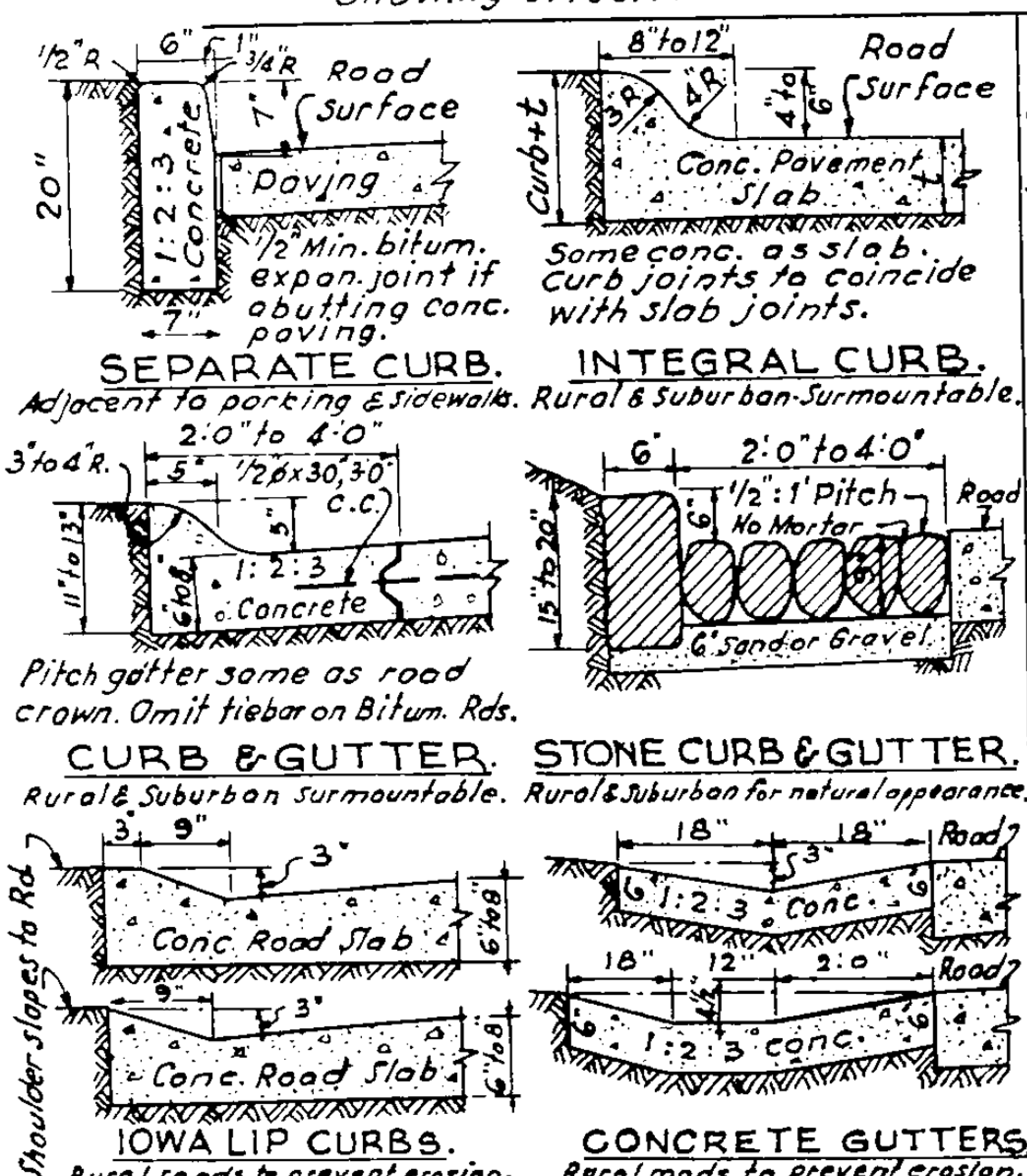


FIG. C - CURBS & GUTTERS.

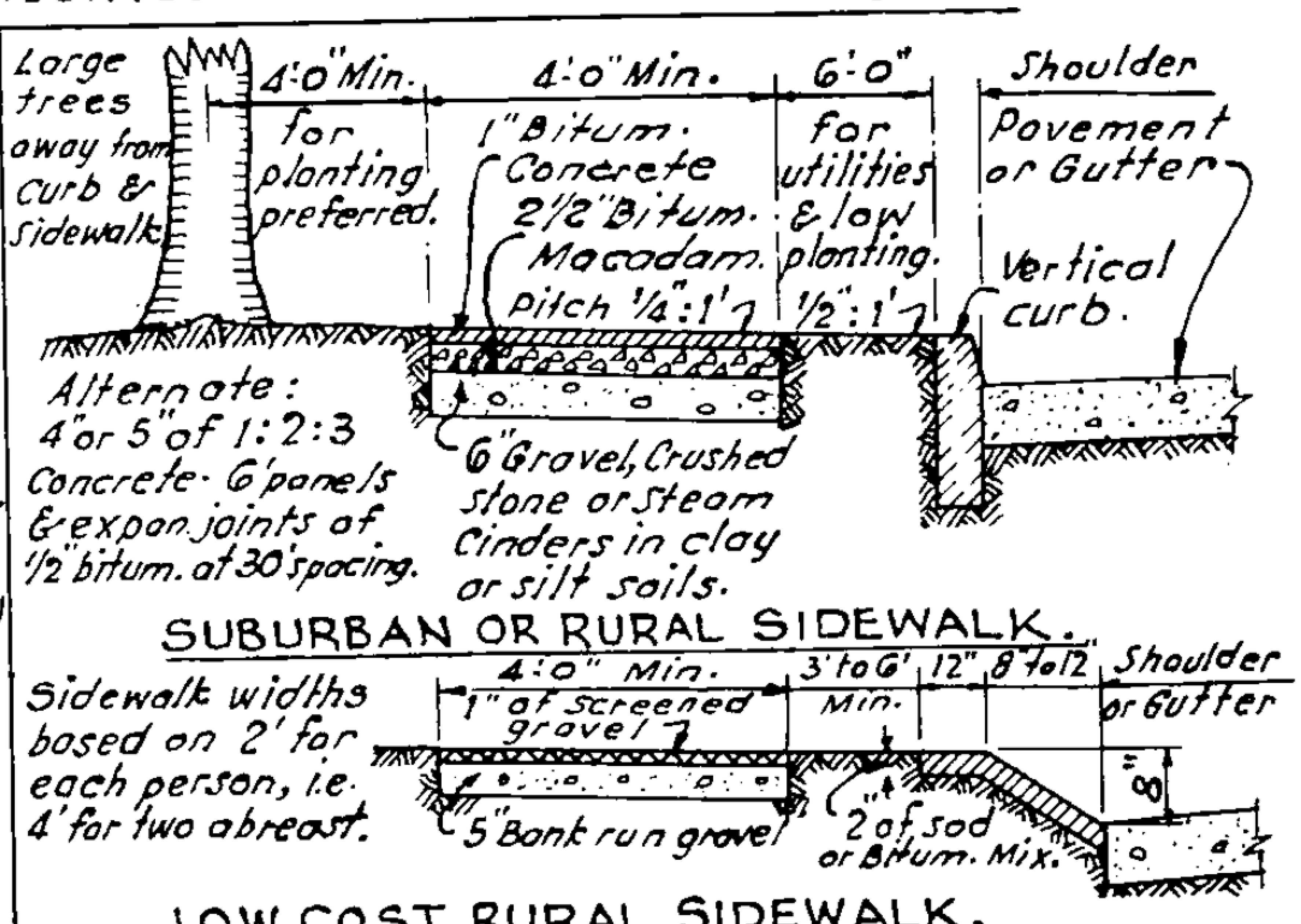


FIG. D - SIDEWALKS.

TABLE E - PEDESTRIANS, PER DAY JUSTIFYING CONSTRUCTION OF SIDEWALKS.**

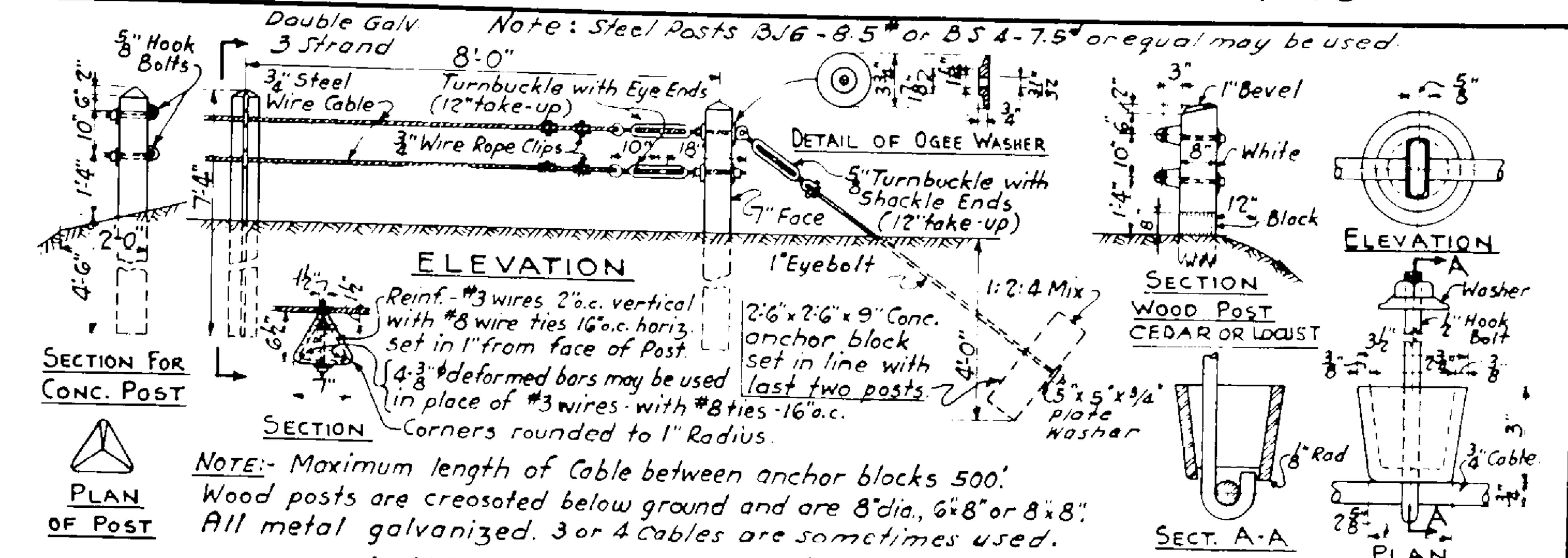
Road Design Speed M.P.H.	One Sidewalk. 30 to 100 Vehicles per hour.	One Sidewalk. Over 100 vehicles per hour.	Two Sidewalks. 50 to 100 vehicles per hour.	Two Sidewalks. Over 100 vehicles per hour.
30, 40, 50	150	100	500	300
60, 70	100	50	300	200

Two sidewalks preferable to avoid crossing.

NOTES: Separate concrete curb and gutter: Install 1/2" bitum. non-extruding expan. joints at 20' transverse intervals, and longitudinally adjacent to any conc. slabs, sidewalks or structures. Precast units; length: 4' min. for closures, 5' min. for radials, 10' max. for straights; align with cast-in dowels or keys. Curb or gutter cast integral with or doweled to a pavement must have joints coincide with pavement joints. Vertical curbs are used adjacent to sidewalks. Rounded or sloping curbs may be crossed by vehicles.

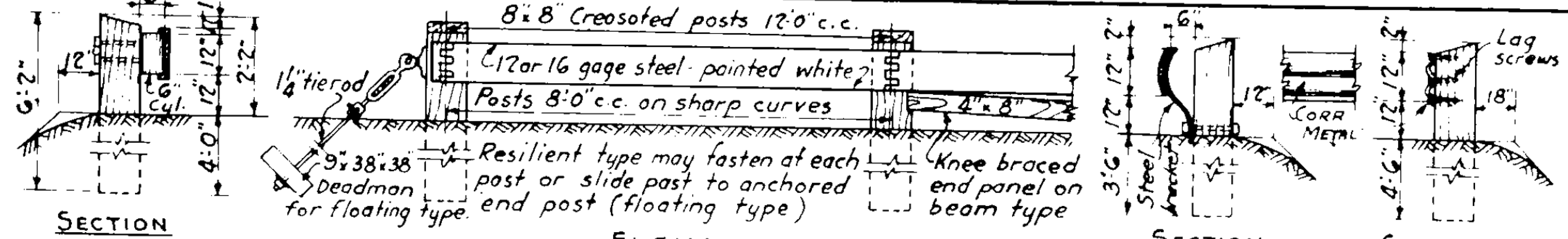
* Adapted from Universal Atlas Cement Co. and N.J. State Highway Dept.
** From A.A.S.H.O.

ROADS - GUARD RAIL DETAILS



WIRE CABLE (MOST WIDELY USED WHERE SNOW IS PLOWED)

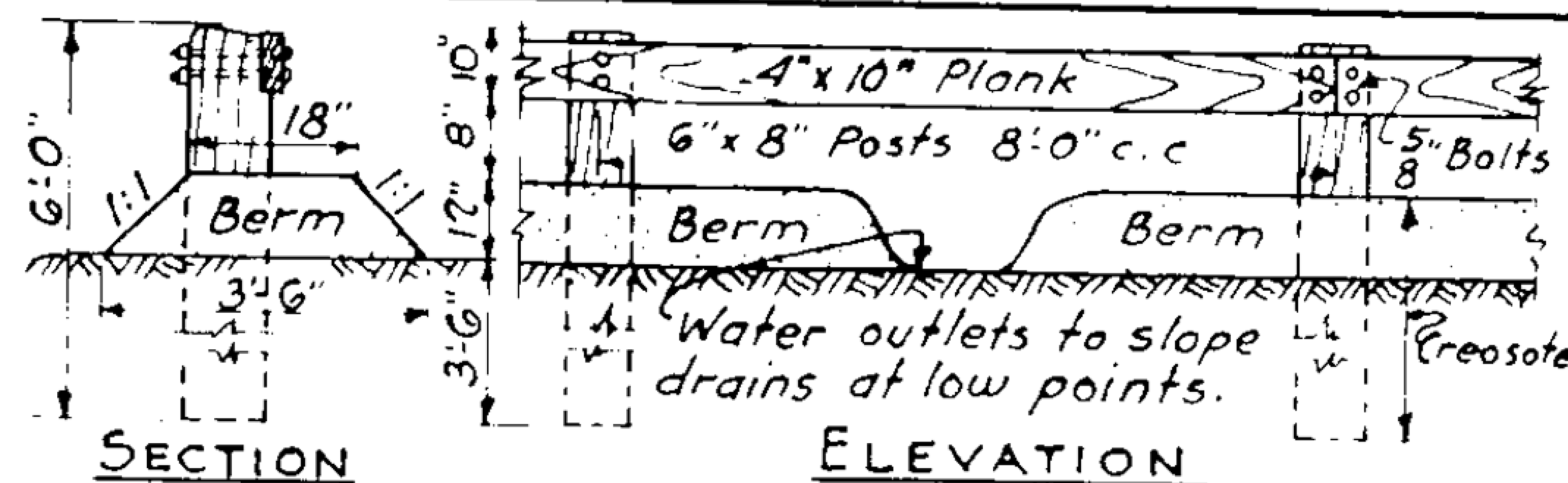
ALTERNATE OFFSET CABLE SUPPORT



RESILIENT TYPE (Patented, see Mfr. details)

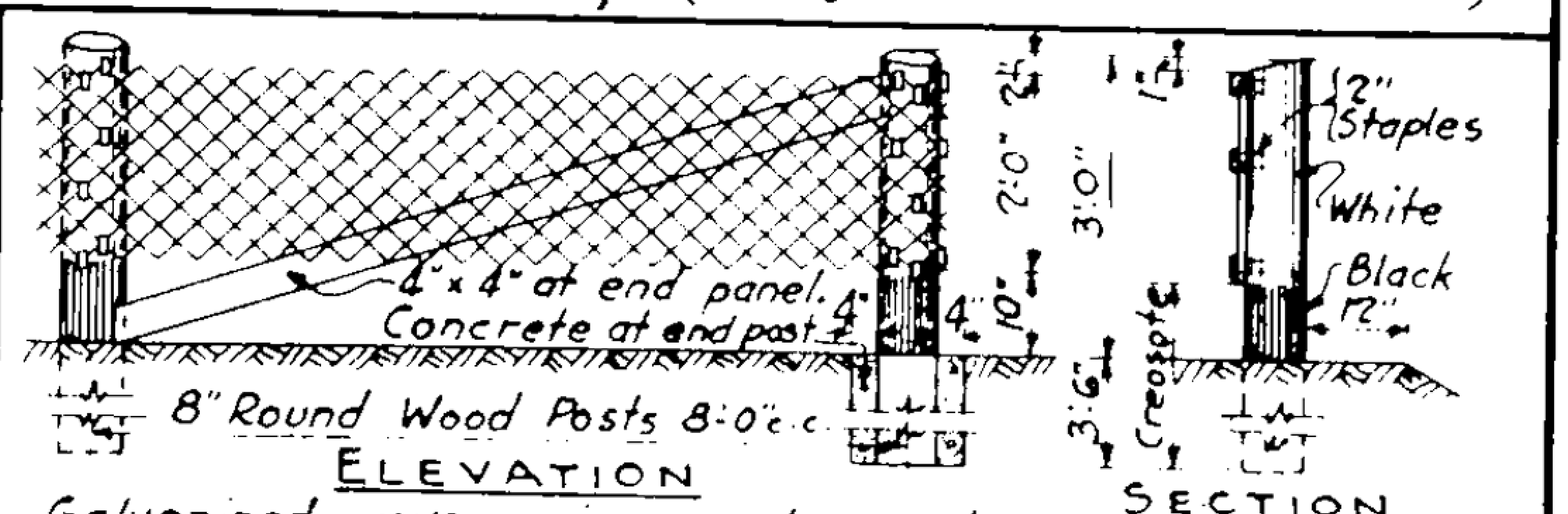
STEEL PLATE (FOR HEAVY TRAFFIC CLASS "A" & "B" ROADS)

BEAM TYPES (Mostly Patented, see Mfr. details)



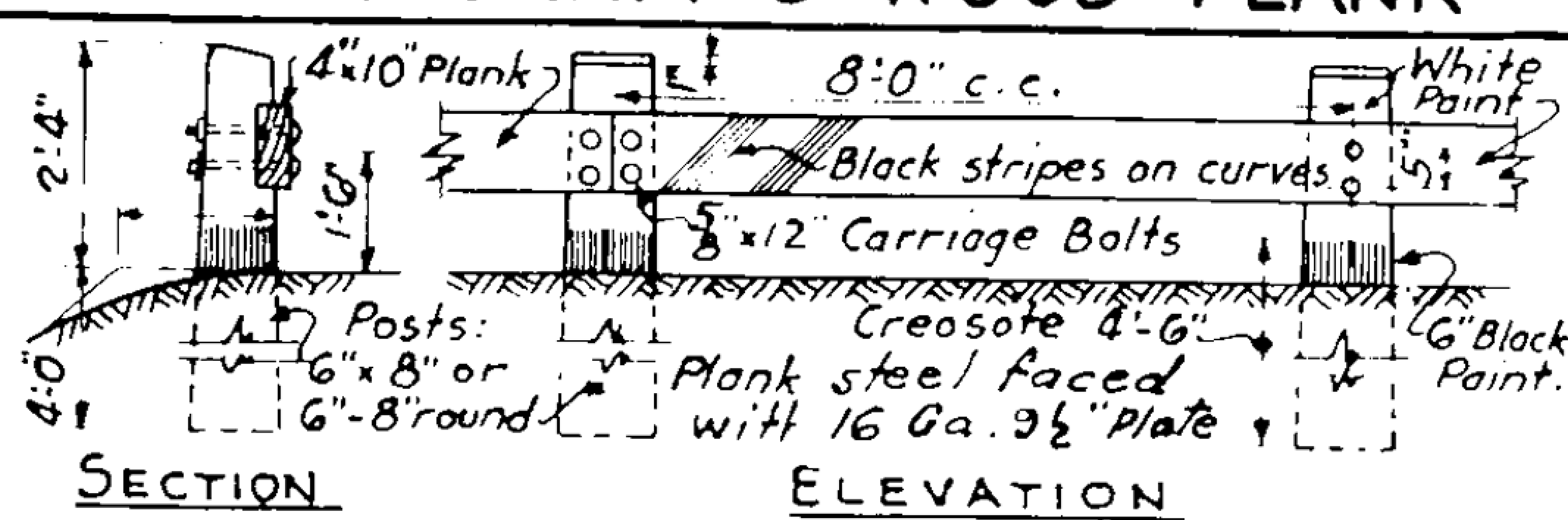
Earth berm may be bituminous treated or sodded.

EARTH BERM & WOOD PLANK

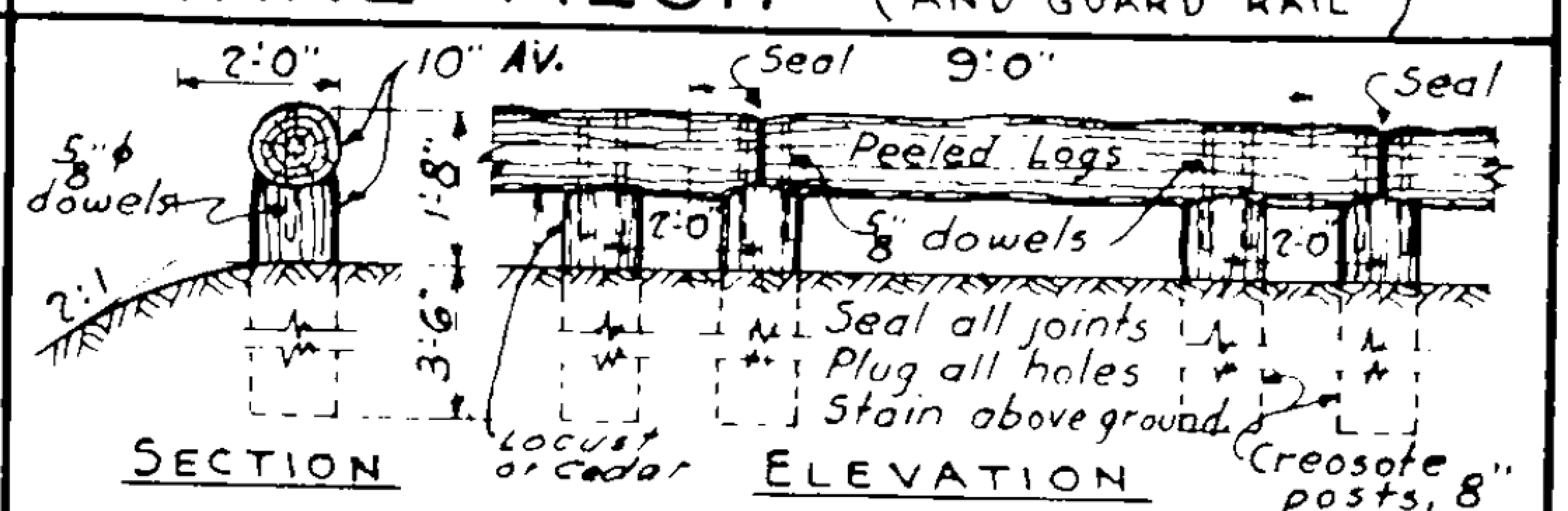


Galvanized woven wire or galvanized expanded metal.

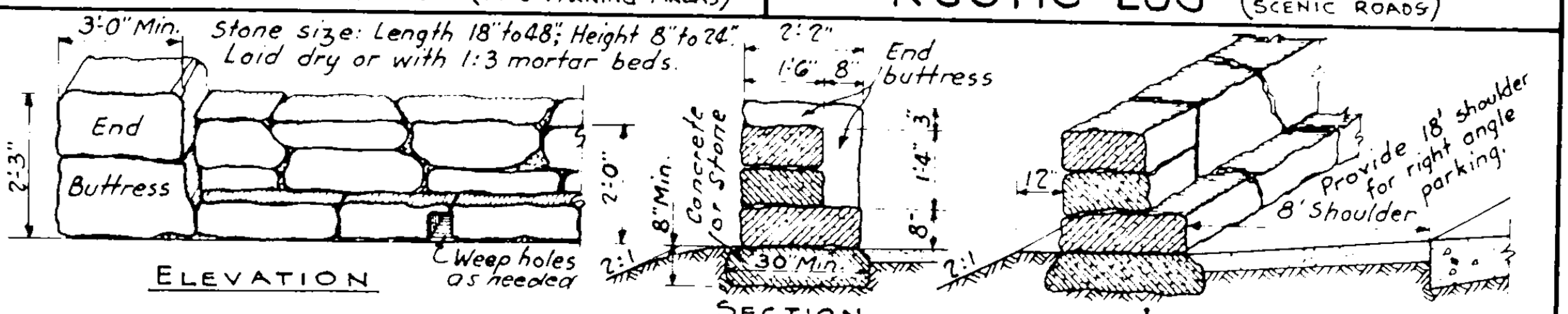
WIRE MESH (USED FOR FENCE AND GUARD RAIL)



WOODEN PLANK (FOR LOW SPEED ROADS AND PARKING AREAS)



RUSTIC LOG (USED FOR SCENIC ROADS)



STONE MASONRY (USED FOR SCENIC OVERLOOKS)

Ref.: Design of Highway Guards by Highway Research Board, N.Y. State Div. of Highways and Booklets 124 & 474 Bethlehem Steel Co.

ROADS-LOCATION OF STRUCTURES & UTILITIES

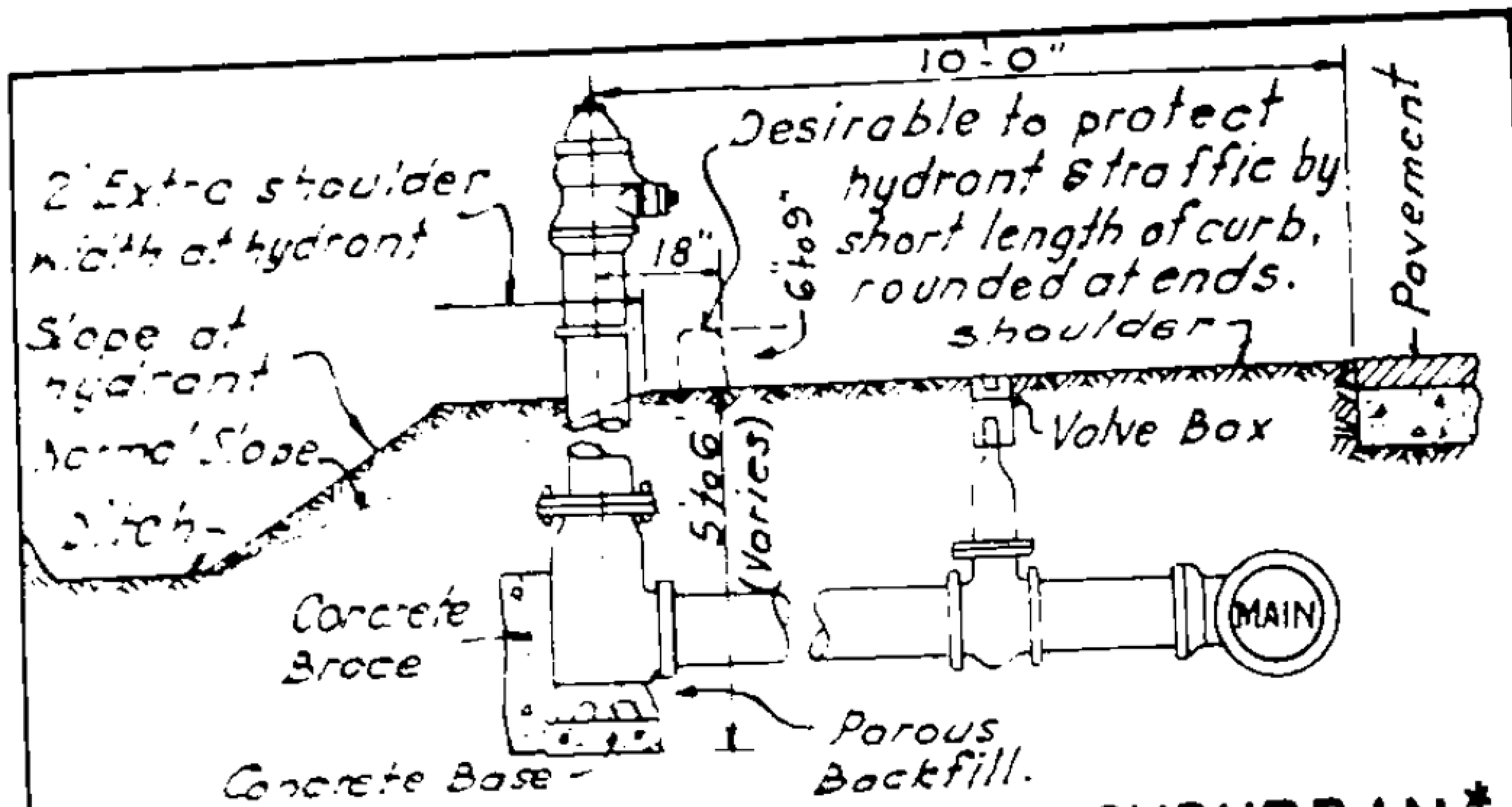


FIG. A - HYDRANT - RURAL OR SUBURBAN.*

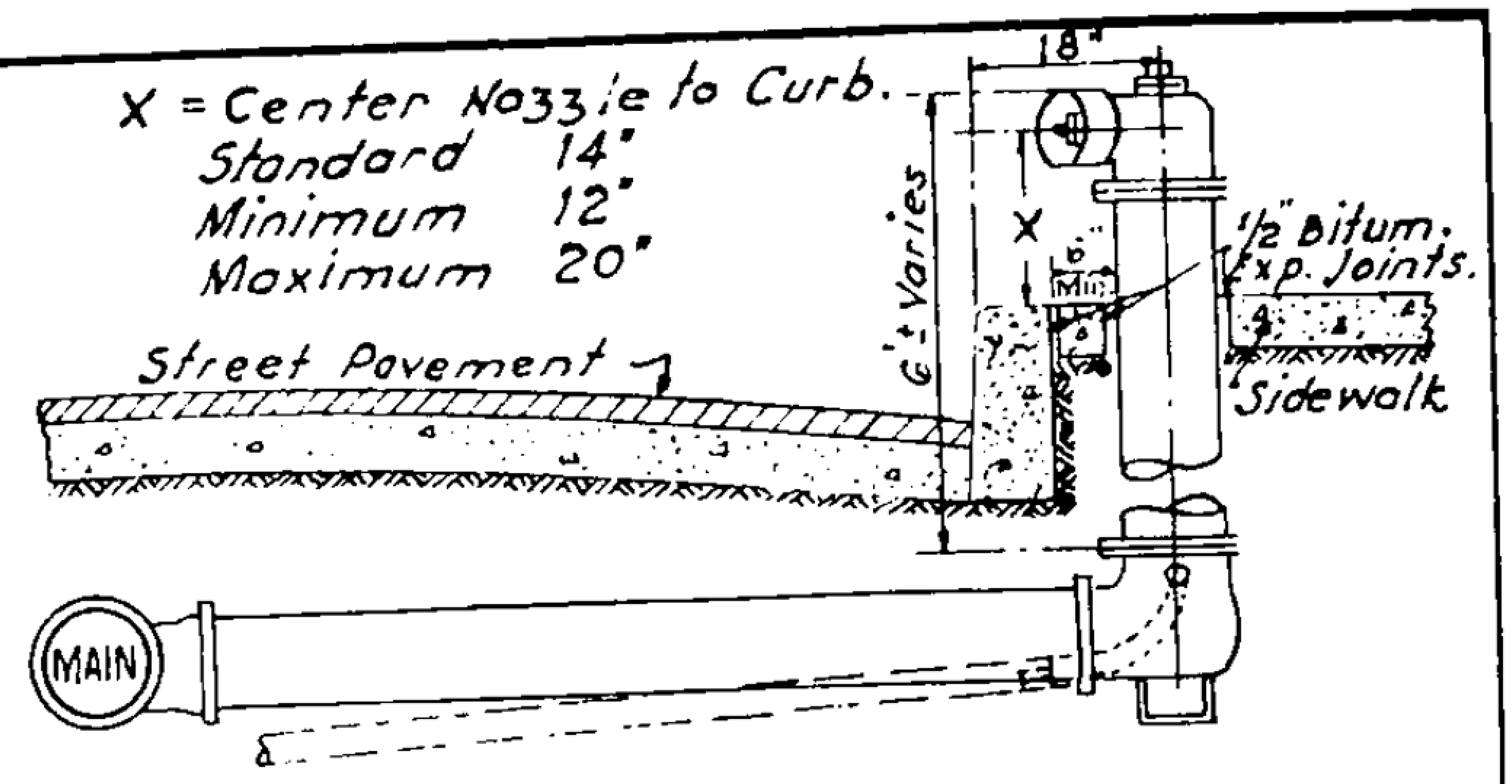


FIG. B - HYDRANT - URBAN.*

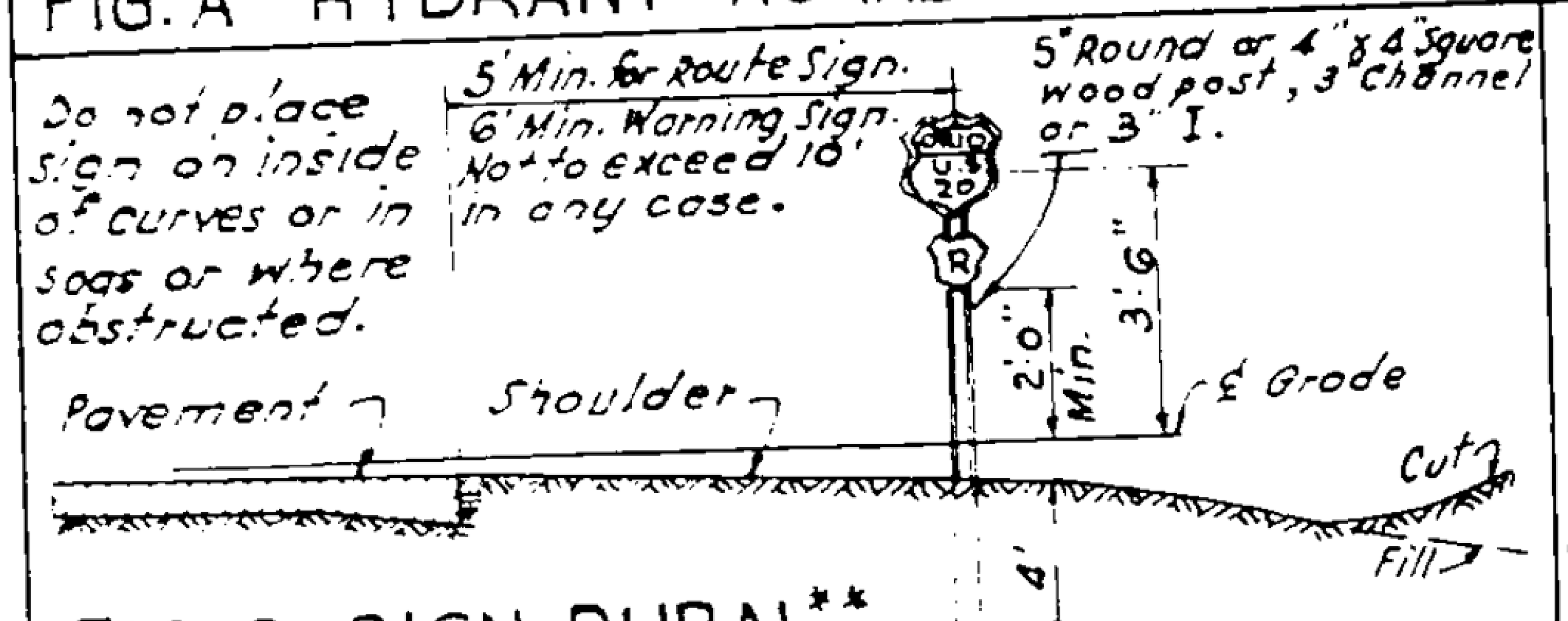


FIG. C - SIGN-RURAL.**

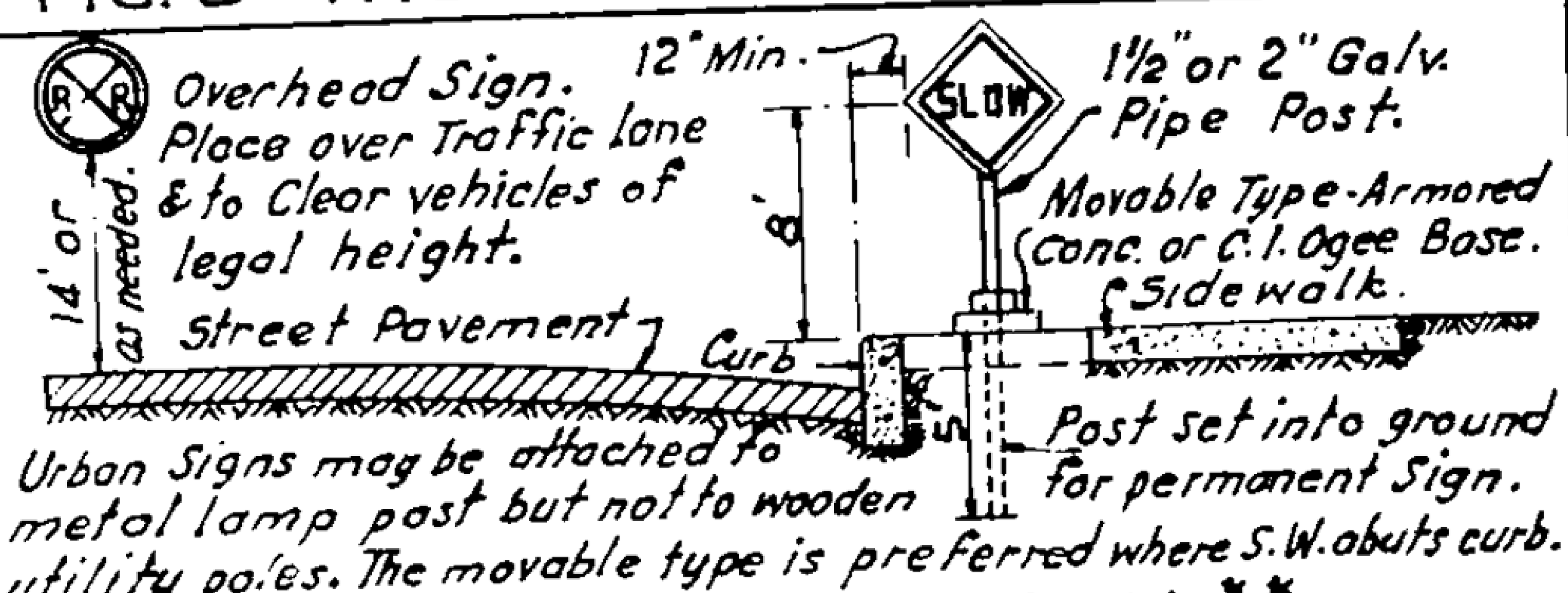


FIG. D - SIGN-URBAN.**

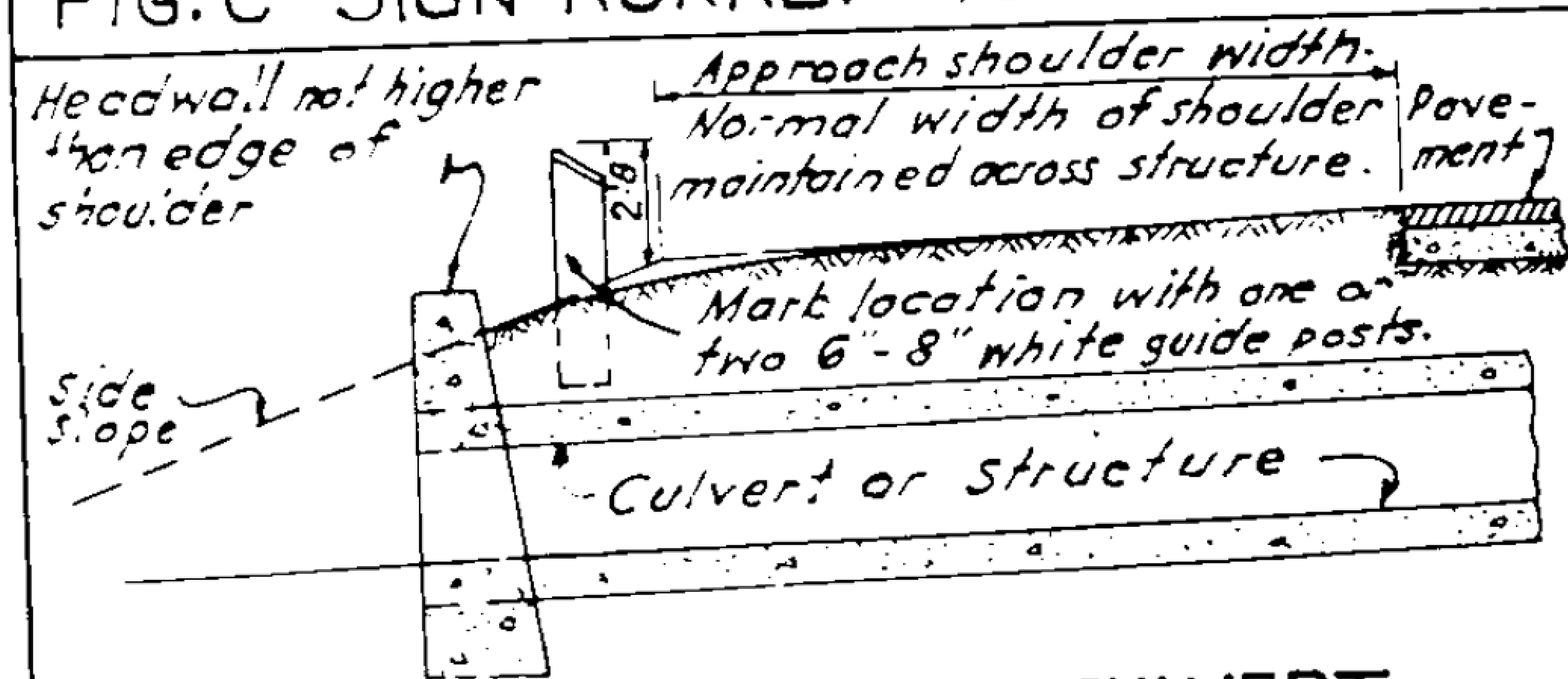
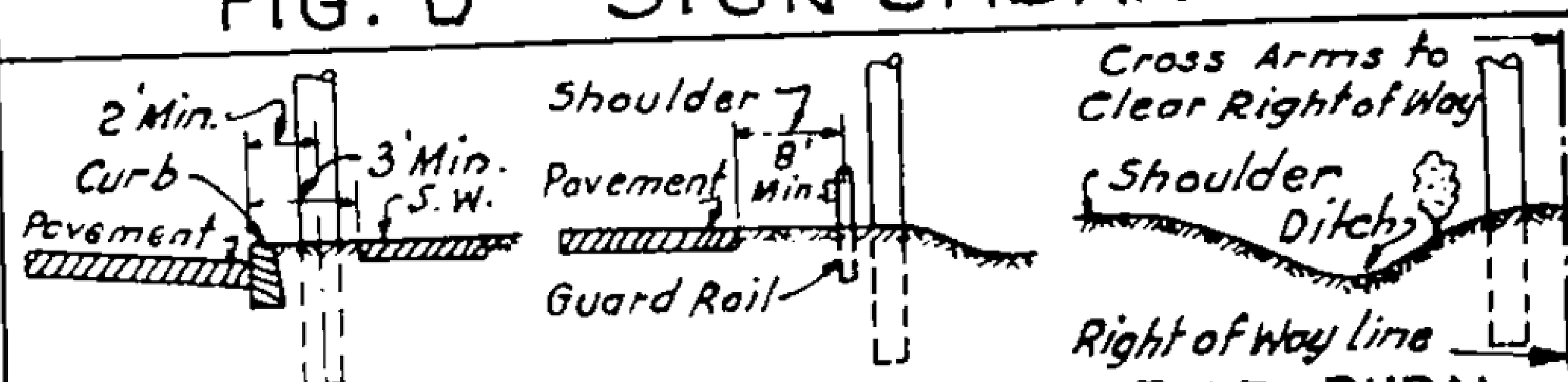


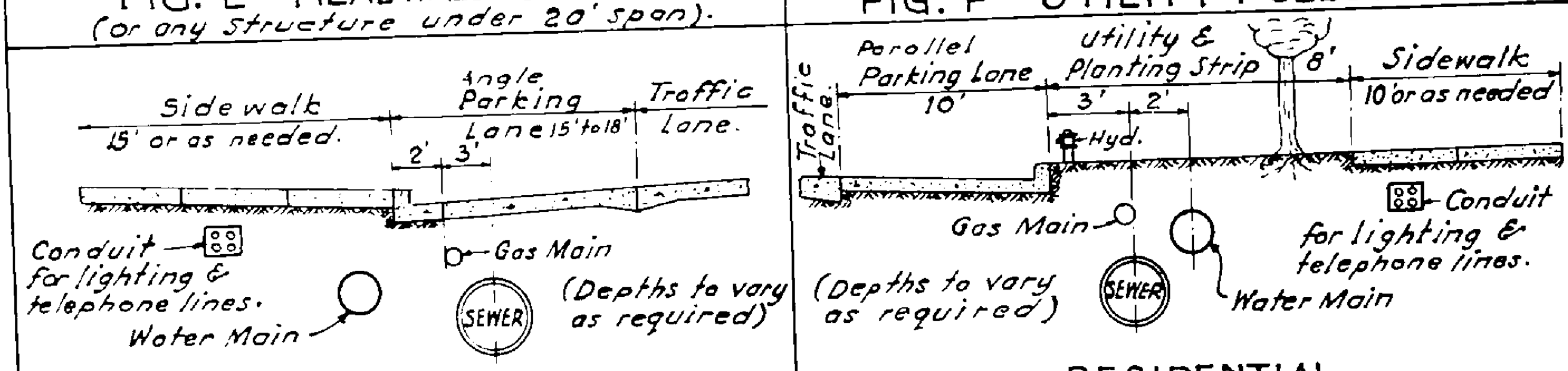
FIG. E - HEADWALL-CULVERT
(or any Structure under 20' span).



POLE-URBAN. POLE-RURAL. POLE-RURAL.

Utility poles, when allowed on Right of Way, should be so placed that traffic is protected by curb, guard rail or ditch. Utility lines should be underground or well away from Highway whenever practicable.

FIG. F - UTILITY POLES.



BUSINESS RESIDENTIAL

FIG. G - PROVISION FOR PUBLIC UTILITIES.***

Showing underground utilities located so openings are available without interfering with through traffic.

GENERAL: † The following notes are applicable to all roads, streets and highways. The erection of electric light, power and telephone poles within the Right of Way should be discouraged, except those necessary for the service of the highway and its facilities. Underground construction is preferable to the erection of pole lines. When underground electric, water, sewerage or other facilities are constructed within the Right of Way they should not be installed beneath any area to be used for the construction of paved traffic lanes except for crossing the highway. Where underground utility lines which require maintenance, repair or replacement cross highways or streets they should be placed in service tunnels under the pavement to insure undisturbed operation of traffic.

* Adapted from Tratman Modern Construction, Eng. News Record. ** Adapted from Manual of Uniform Traffic Control, A. A. S. H. O. *** Adapted from R. E. Toms, P.R.A. Chicago Designs.
† Adapted from Interregional Highways, President of the United States.

ROADS - STREET & HIGHWAY LIGHTING *

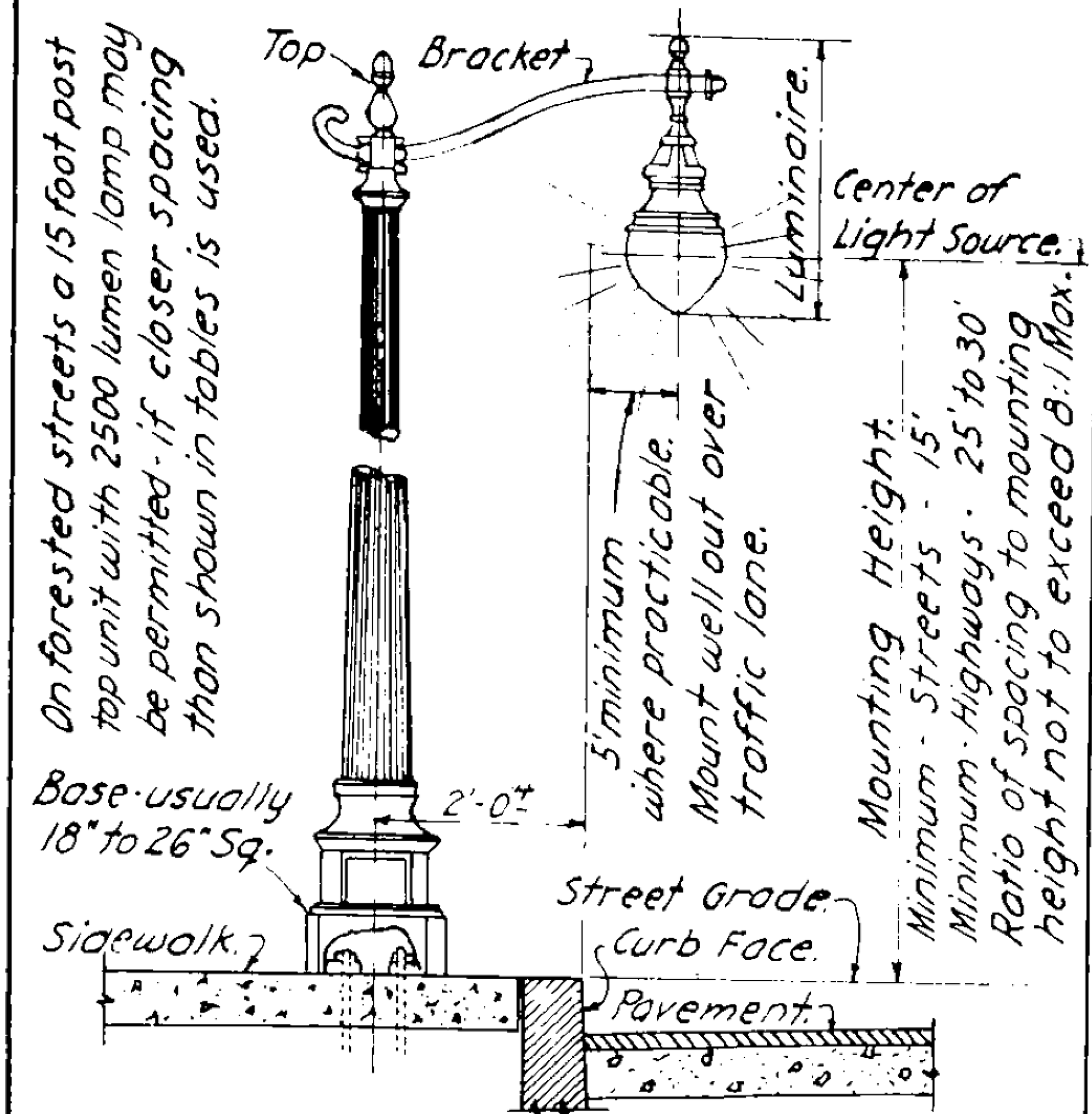


FIG. A - LIGHTING UNIT - URBAN.

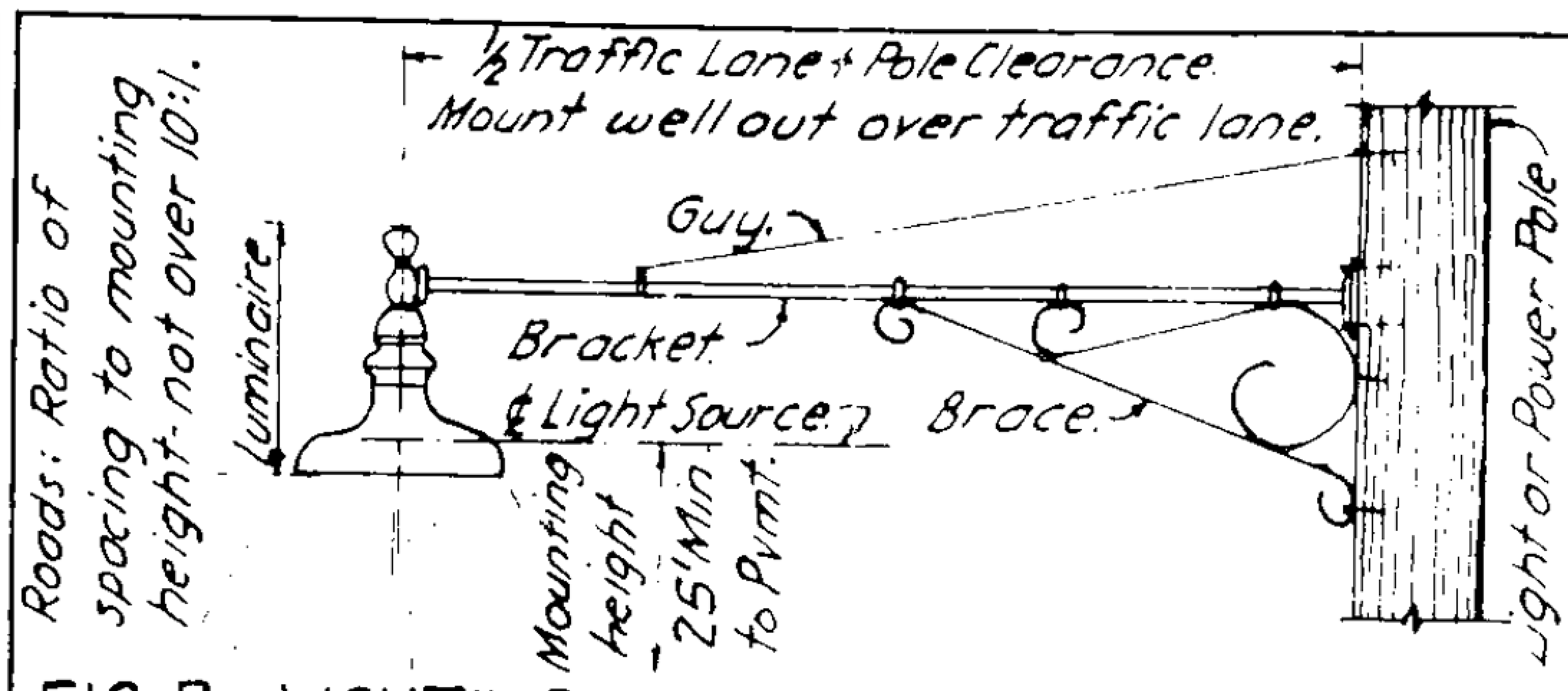


FIG. B - LIGHTING UNIT - RURAL OR SUBURBAN.

TABLE C - MINIMUM MOUNTING HEIGHTS FOR VARIOUS LAMP SIZES.

LAMP SIZE LUMENS*	CONCENTRATED (a)	SEMI-CONCENTRATED (b)	DIFFUSING GLOBES (c)
1,000	15'	15'	15'
2,500	18'	18'	18'
4,000	20'	18'	18'
6,000	22'	18'	18'
10,000	25'	21'	18'
15,000	28'	24'	18'
25,000	33'	27'	20'

Approximate beam candlepower to lumen rating: a = 6/10 ; b = 3/10 ; c = 1/10. *One lumen per Sq. Ft. = One footcandle

TABLE D - LIGHTING ARRANGEMENTS TO GIVE 0.2 TO 0.5 LUMENS PER SQ. FT. ON LIGHT COLORED SURFACES FOR HIGHWAYS.** (Less than four intersections per mile - few pedestrians)

PAVEMENT WIDTH	LAMP LUMENS	MOUNTING HEIGHT FT.	LUMINAIRE SPACING FT.	PAVEMENT WIDTH	LAMP LUMENS	MOUNTING HEIGHT FT.	LUMINAIRE SPACING FT.†
2 Lanes	6,000	25 - 30	240 - 250	4 Lanes	6,000-10,000	25 - 30	240 - 250
	6,000	25	200	(Illuminate both	6,000-10,000	25	200
	4,000	25	125	sides).	6,000	25	125
3 Lanes	6,000-10,000	25 - 30	240 - 250				
(Illuminate both	6,000-10,000	25	200				
sides).	4,000	25	125				

**Dark Surface - Provide 0.3 to 1.0 Lumen per Sq. Ft.
Dull Black Surface - Provide .0 to 20 Lumens per Sq. Ft.
On divided highways - light each roadway separately.
† Install units on outside of curves & crests of hills.

TABLE E - LIGHTING ARRANGEMENTS TO GIVE APPROXIMATE ILLUMINATION VALUES OF TABLE F FOR STREETS. (Trafficways other than highways)

TRAFFIC - Nº OF VEHICLES MAX. NIGHT HOUR - BOTH DIRECTIONS	LAMP LUMENS	MOUNTING HEIGHT - FT.	LUMINAIRE SPACING - FT.	TRAFFIC - Nº OF VEHICLES MAX NIGHT HOUR BOTH DIRECTIONS	LAMP LUMENS	MOUNTING HEIGHT - FT.	LUMINAIRE SPACING - FT.
Very Light Traffic	1,000	15	90-110 Stagger	Medium Traffic	6,000	20 - 25	100-120 Stagger
Under 150 Vehicles.	2,500	20 - 22	130-170 "	500-1200 Vehicles.	10,000	22 - 27	130-170 "
	4,000	25 - 30	200-250 Center		15,000	25 - 30	130-170 "
Light Traffic	2,500	16 - 18	100-120 Stagger.	Heavy Traffic	10,000	24 - 28	100-150 Opposite.
150-500 Vehicles.	4,000	20 - 25	130-170 "	1200-2400 Vehicles.	10,000	24 - 28	75-90 Stagger.
	6,000	22 - 25	130-170 "		15,000	24 - 28	150-180 Opposite.
				2400-4000 Vehicles.	15,000	25 - 30	100-150 Opposite.
				Over 4000 Vehicles.	15,000	25 - 30	100 Opposite.

Larger lamps or closer spacing are required on business streets. - See Table F.

TABLE F - AVERAGE FOOTCANDLES - MINIMUM FOR NIGHT TRAFFIC SAFETY.

	VERY LIGHT TRAFFIC		LIGHT TRAFFIC		MEDIUM TRAFFIC		HEAVY TRAFFIC		VERY HEAVY TRAFFIC	
	AVG.	MIN.	AVG.	MIN.	AVG.	MIN.	AVG.	MIN.	AVG.	MIN.
Principal Business Streets.			0.4	0.1	0.8	0.2	1.2	0.3	1.5	0.4
Secondary Business Stress.			0.3	0.07	0.6	0.15	1.0	0.25	1.3	0.3
Through High Speed Arteries (Other than business streets).			0.3	0.07	0.6	0.15	1.0	0.25	1.3	0.3
Express Freeways & Viaducts.					0.4	0.1	0.8	0.2	1.2	0.3
Residence Streets.	0.1	0.02	0.2	0.05	0.4	0.1				
Industrial Warehouse Streets.	0.1	0.02	0.2	0.05	0.4	0.1				

These recommendations apply where pavement reflection characteristics are favorable as in the case of light concrete or light finished asphaltum. Somewhat higher footcandle values should be employed where street surface reflections are less favorable.

* Recommended practice of Street Lighting 1940 And Code of Highway Lighting 1937. - Illuminating Eng. Society.

ROADS - URBAN STREETS - 1

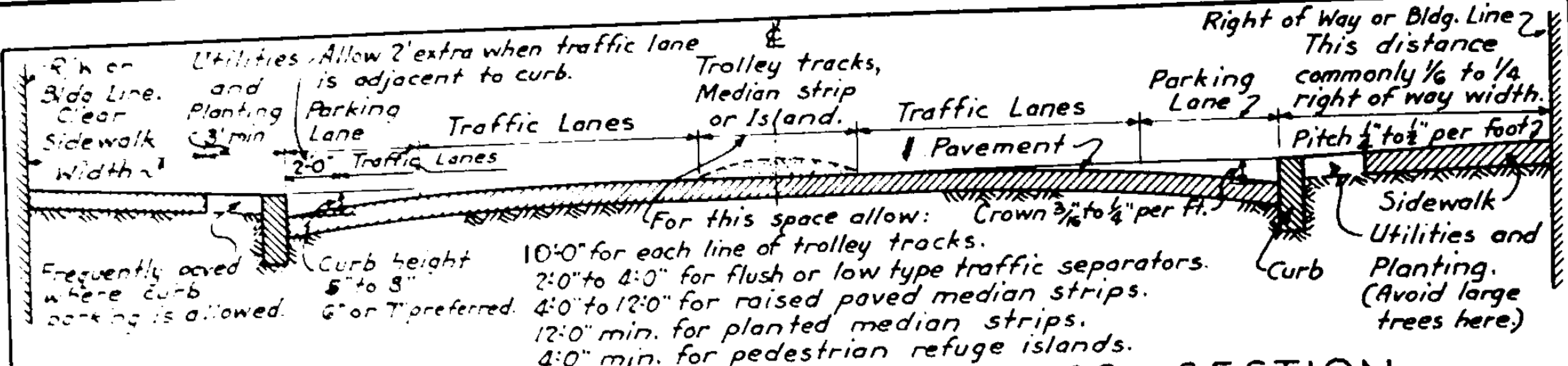


FIG. A - ELEMENTS OF STREET CROSS-SECTION.

TABLE B - CLASSIFICATION OF URBAN STREETS.

CLASS OF STREET	DESCRIPTION
Primary Business	Very heavy traffic - Commercial buildings of 4 or more stories.
Secondary Business	Heavy traffic - Commercial buildings of 4 or less stories.
Primary Residential	Medium traffic - Multi-family houses and apartment buildings.
Minor Residential	Light traffic - Single family houses.
Industrial	Heavy traffic - Dock, warehouse and factory districts.
Boulevards, Parkways	Restricted traffic - Divided roadways, landscaped or planted.
Viaducts	Usually heavy traffic - Street elevated over low area, R.R. yards, etc.
Express Highways	Heavy through traffic - May be at grade, elevated or depressed.

TABLE C - RECOMMENDED WIDTHS.

CLASS OF STREET	TRAFFIC LANES	SIDEWALK WIDTH	PARKING LANES	PAVEMENT TYPE	SIDEWALK TYPE	REFUGE ISLANDS
Primary Business	6-10' to 12' Lanes.	15' to 30'	Parallel parking 10'. Angle parking 15' to 18'.	Concrete, Sheet Asphalt, Bituminous Concrete, Brick or other high type block pavements. (e)	Concrete, Bituminous Concrete, Brick, Tile, Asphalt Mastic or Stone Setts.	4' min. width where pedestrians must cross 3 or more lanes of moving traffic. 4' min. width loading platforms where needed for busses and trolleys.
Secondary Business	4-10' to 12' Lanes.	10' to 20'				
Industrial	According to traffic.	6' to 15'				
Primary Residential	2-10' lanes minimum.	6' to 15'	2-8' lanes minimum.			
Minor Residential	2-10' lanes (a)	4' to 6' (c)	1 or 2-8' lanes (a)	Concrete, Macadam, Bituminous or Brick.	Concrete, Bituminous, Cinders, Gravel, Flags or Brick.	
Boulevards, Parkways, Viaducts, Bridges, Tunnels	10' to 12' lanes for low speeds, 12' lanes for high speeds.	Provide 4' in width for each two persons abreast	8' to 10' for parallel parking where permitted. (b)	Concrete, High type Bitum. or High type Block. (e)	Concrete or High type bituminous.	

(a) For two-way streets allow for 2 traffic lanes and one parking lane, min. For one-way streets allow one traffic lane and 2 parking lanes, min.
(b) Provide for disabled vehicles and scenic overlooks where continuous parking is prohibited.
(c) Suburban developments show tendency to eliminate walks along street to provide privacy; Service and access walks may be planned distinct from the street system.
(d) Sidewalks frequently omitted from express highways, viaducts and tunnels. (Safety walk of 2' min. with barrier curb is desirable)
(e) Block type pavements widely used for industrial streets, viaducts, bridges and tunnels.

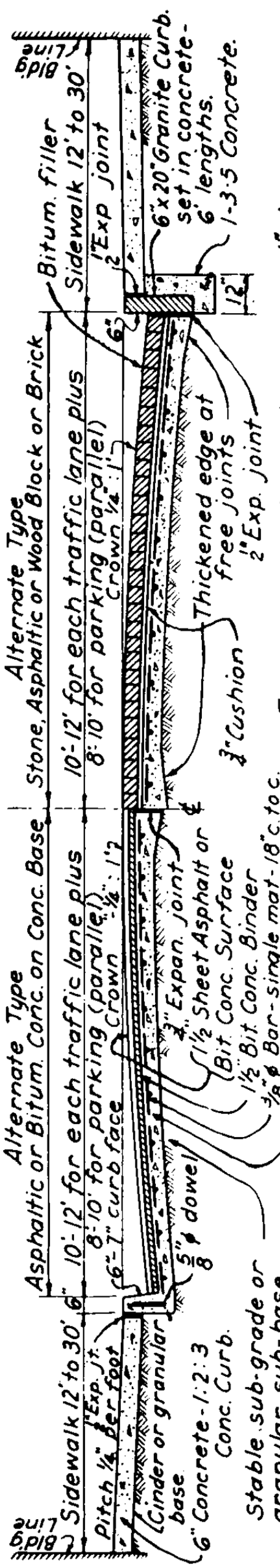
TABLE D - TRAFFIC LANES FOR THROUGH TRAFFIC

FOR URBAN STREETS CARRYING OTHER THAN LOCAL TRAFFIC USE THESE WIDTHS.

DAILY TRAFFIC	TRAFFIC LANES	MINIMUM CURB TO CURB *	DAILY TRAFFIC	TRAFFIC LANES	MINIMUM CURB TO CURB *
Up to 750	2-10' Lanes Min.	24'	4,000 to 20,000	4 or 6-11' or 12' Lanes	48' **
750 to 4,000	2-11' or 12' Lanes	26'	Over 20,000	6-11' or 12' Lanes	70' **

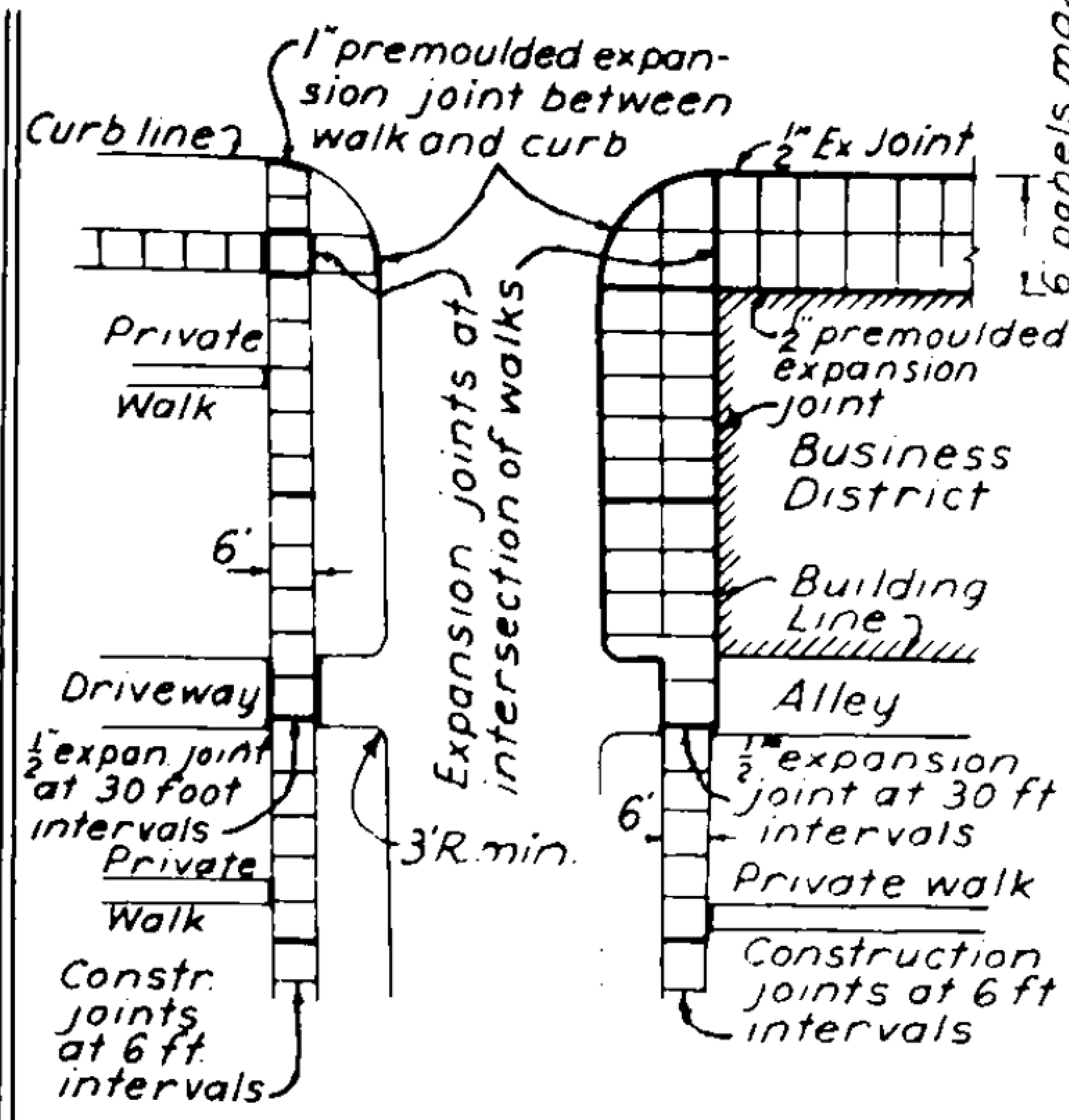
* Bridges, Viaducts, Streets, etc. (without parking lanes). ** Plus median strips, islands or street R.R.s.

ROADS - URBAN STREETS - 2

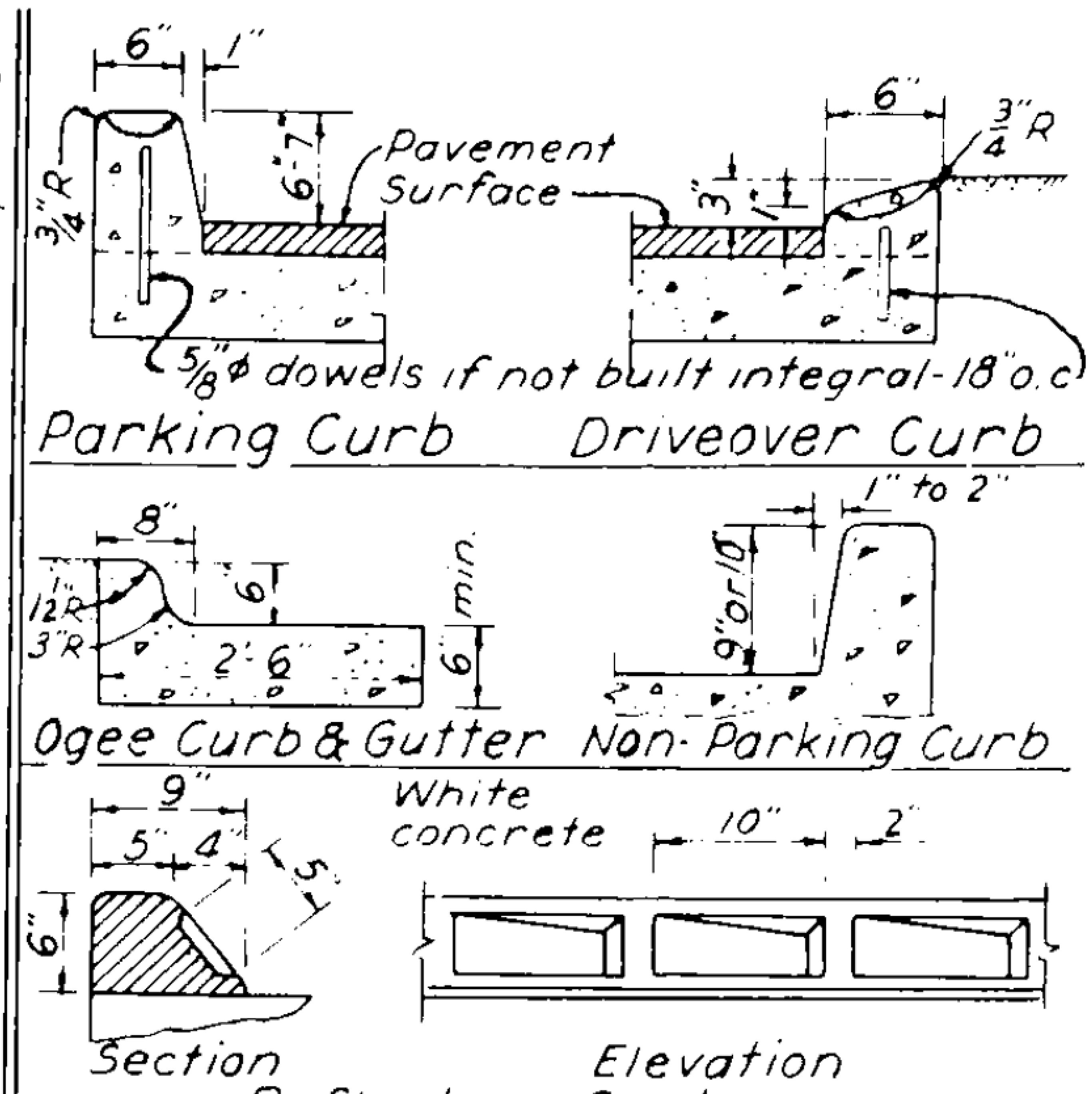


For warped sections: min. crown = 1/8":1', max. crown = 1/2":1'

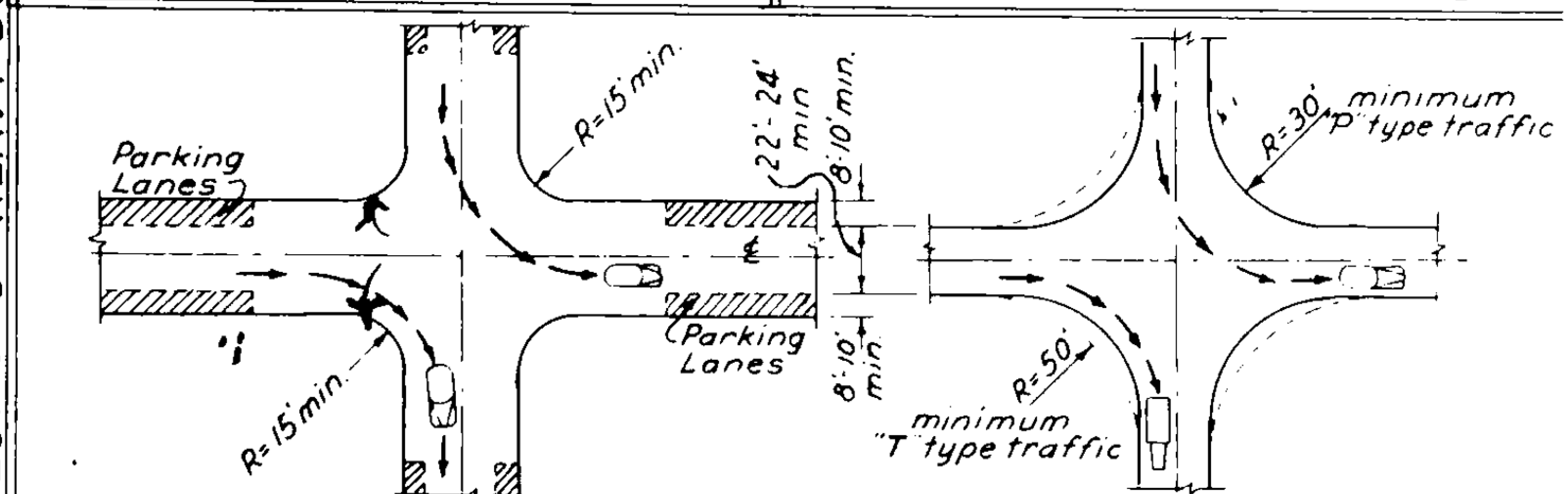
ALTERNATE CROSS-SECTIONS - HEAVY DUTY URBAN STREET



EXPANSION AND CONTRACTION JOINT* DETAILS - CONCRETE SIDEWALKS

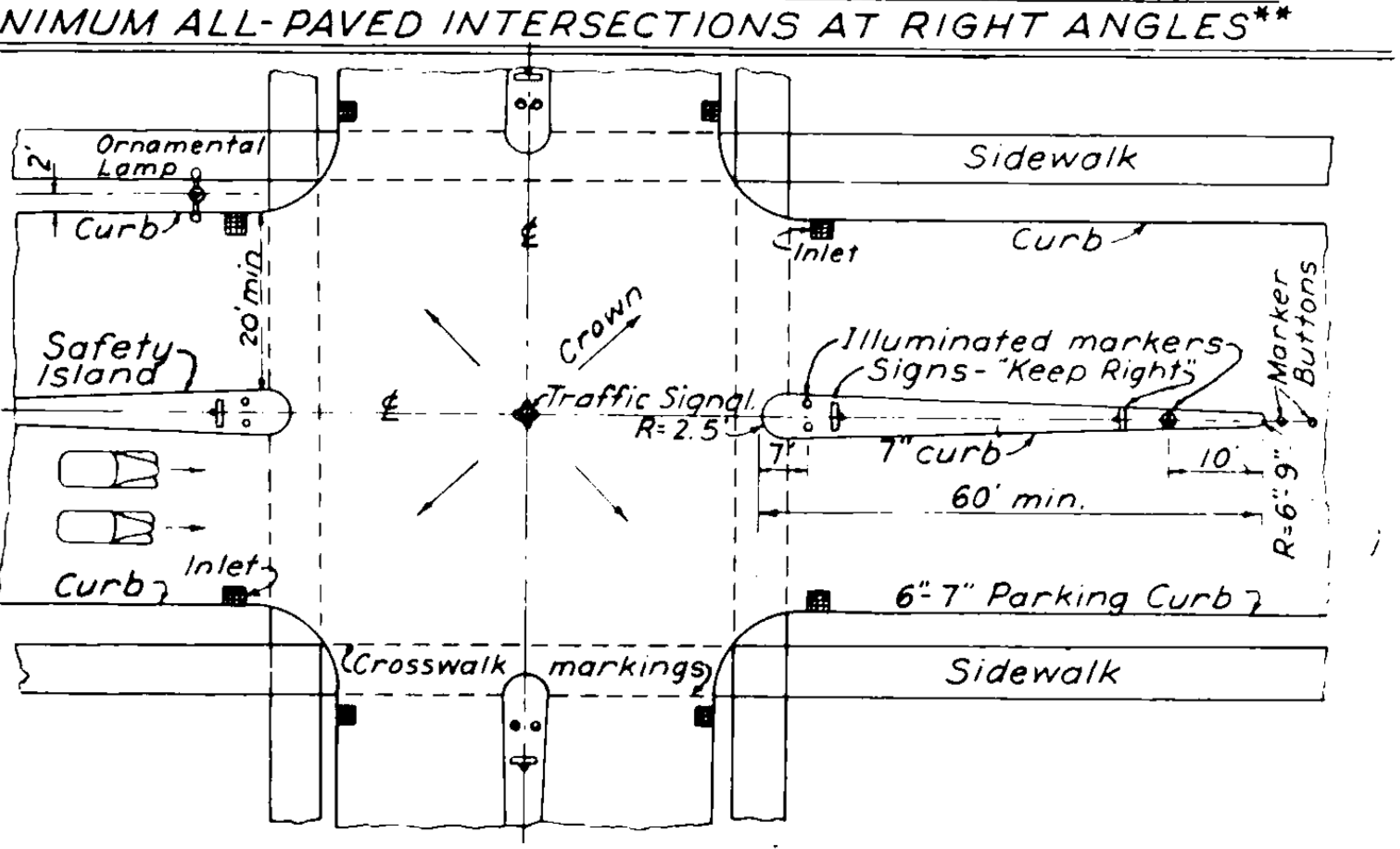


TYPICAL CONCRETE CURBS



WITH PARKING LANES WITHOUT PARKING LANES

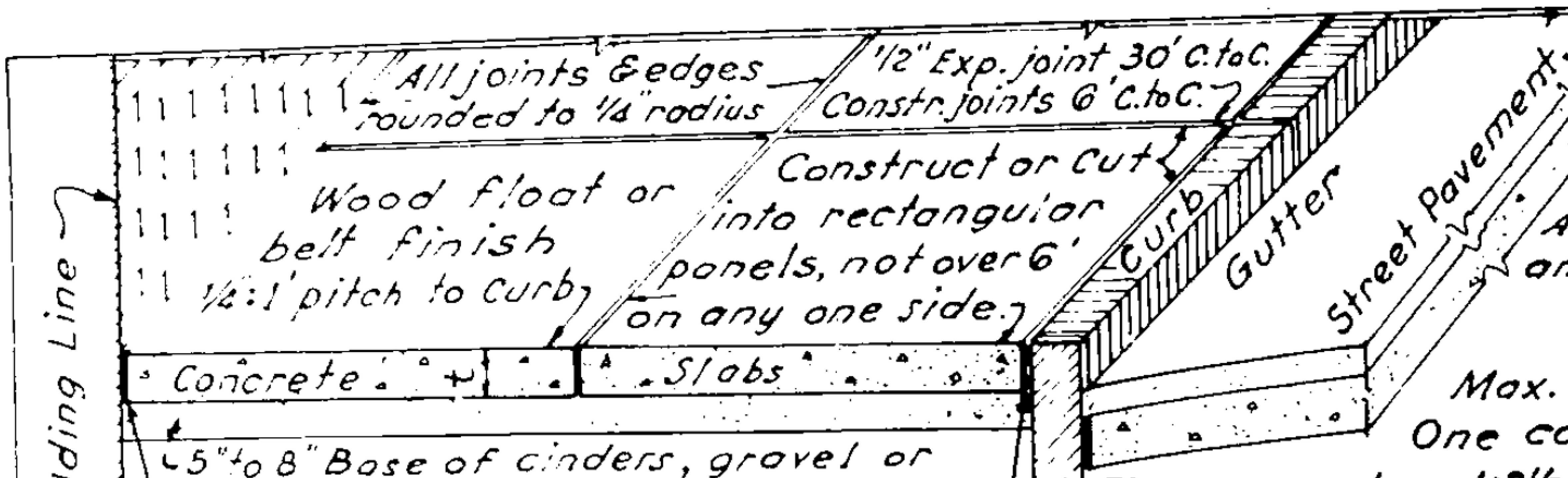
MINIMUM ALL-PAVED INTERSECTIONS AT RIGHT ANGLES**



URBAN STREET INTERSECTION (with safety islands), Four or more traffic lanes and low speed traffic.**

* From Portland Cement Association. ** Adapted from Am. Association of State Highway Officials.

ROADS – URBAN STREETS – 3



5" to 8" Base of cinders, gravel or sand on silt or clay subgrades.

1/2" premolded bitum. expan. joints next to buildings, structures and curbs.
Construction joints may be formed by 1/8" metal plates, removed after finishing, or by cutting slab at least 1/3 full depth.

THICKNESS "t" MIN.
Residential Areas – 5"
At residential driveways – 6"
Business & Industrial Areas – 6"
At business & industrial driveways and alleys – 7" to 8" reinforced.

CONCRETE MIX.
Max. W/C Ratio, 6 gals. per sack.
One course construction 1:2:3.
Two course: base 1:2½:4; top, 1:2 mortar.
Construct top course 1" thick (One course preferred).
Steel trowel finish may be used on flat grades.
Broom or abrasive finish should be used on grades over 5%.

FIG. A – CONCRETE SIDEWALKS.* (See Pg. 3·91)

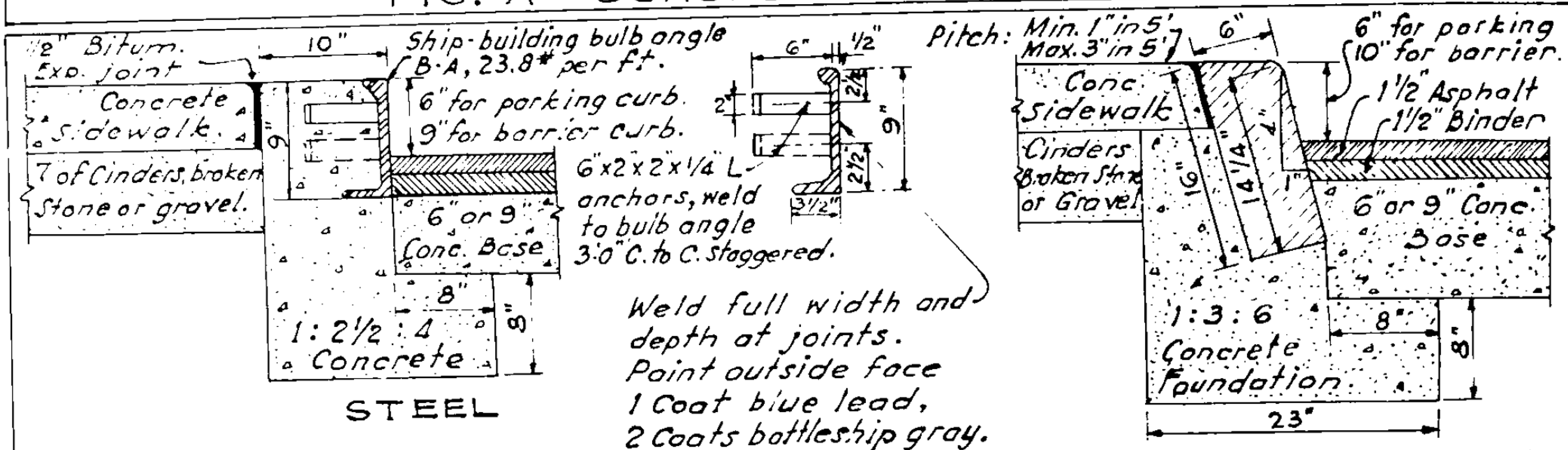
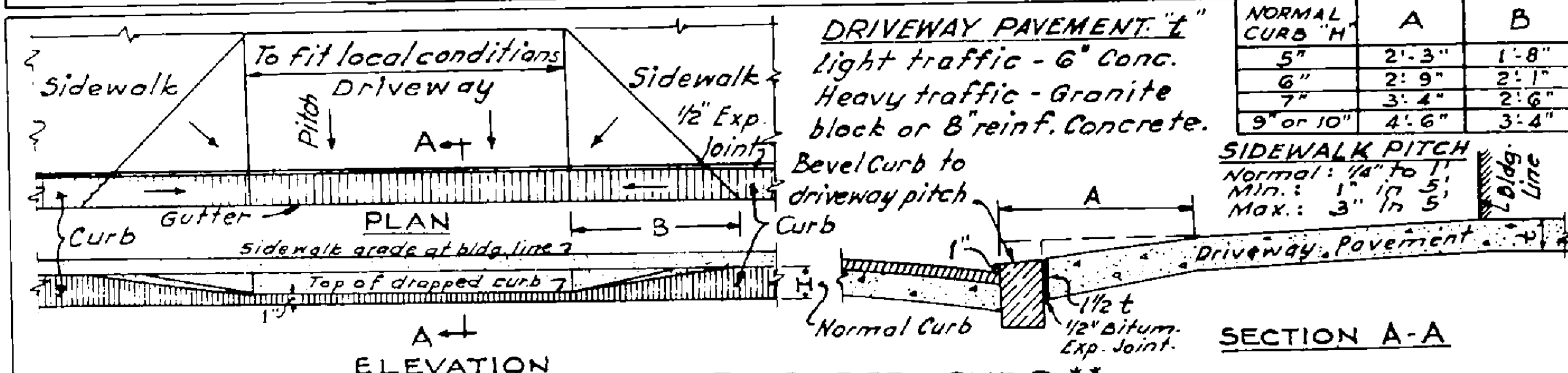


FIG. B – HEAVY DUTY URBAN CURBS.**



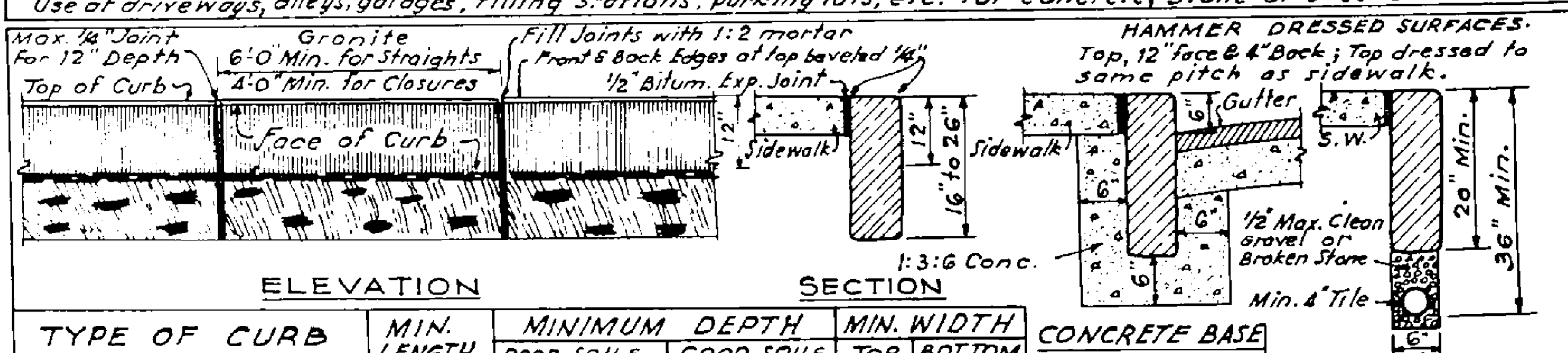
DRIVEWAY PAVEMENT "t"
Light traffic – 6" Conc.
Heavy traffic – Granite block or 8" reinf. Concrete.

NORMAL CURB "H"	A	B
5"	2'-3"	1'-8"
6"	2'-9"	2'-1"
7"	3'-4"	2'-6"
9" or 10"	4'-6"	3'-4"

SIDEWALK PITCH
Normal: 1/4" to 1'
Min.: 1" in 5'
Max.: 3" in 5'

FIG. C – DROPPED CURB.**

Use at driveways, alleys, garages, filling stations, parking lots, etc. For concrete, stone or steel curbs.



HAMMER DRESSED SURFACES.
Top, 12" face & 4" Back; Top dressed to same pitch as sidewalk.

TYPE OF CURB	MIN. LENGTH	MINIMUM DEPTH		MIN. WIDTH	
		POOR SOILS	GOOD SOILS	TOP	BOTTOM
Granite	as shown	20" to 26"	16"	5"	3"
Hard Sandstone & Bluestone	36" to 48"	20" to 25"	16" to 18"	6"	3"
Hard Limestone	36" to 48"	20" to 25"	16" to 18"	6"	3"
Soft sandstone & limestone.	4' to 6'	18" to 24"	16" to 18"	5"	5"

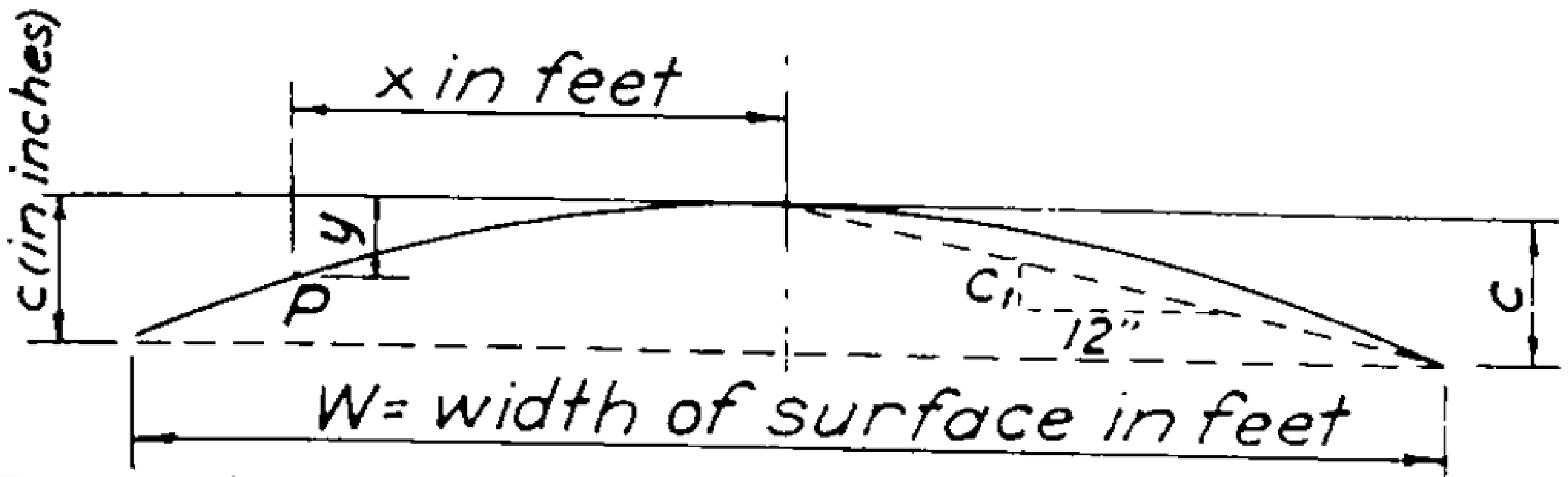
CONCRETE BASE
Poor soils or on Primary Streets. Depth, all types, 16" when set in Concrete.

WITH TILE DRAIN.
For wet soils. Outlet tile at not more than 300' intervals.

FIG. D – STONE CURB DETAILS.***

*Adapted from Portland Cement Assoc. ** Adapted from City of New York.
*** Adapted from Penna. Dept. of Highways & Amer. Public Works Assoc.

ROADS - PARABOLIC CROWN ORDINATES-1



Formulas

$c = c_1\left(\frac{W}{2}\right)$; $y = 4c\left(\frac{x}{W}\right)^2$

Example

Given:

$c_1 = \frac{1}{8}''$; $W = 22'$ and $x = 6'$

Required:

c; y (at any point P)

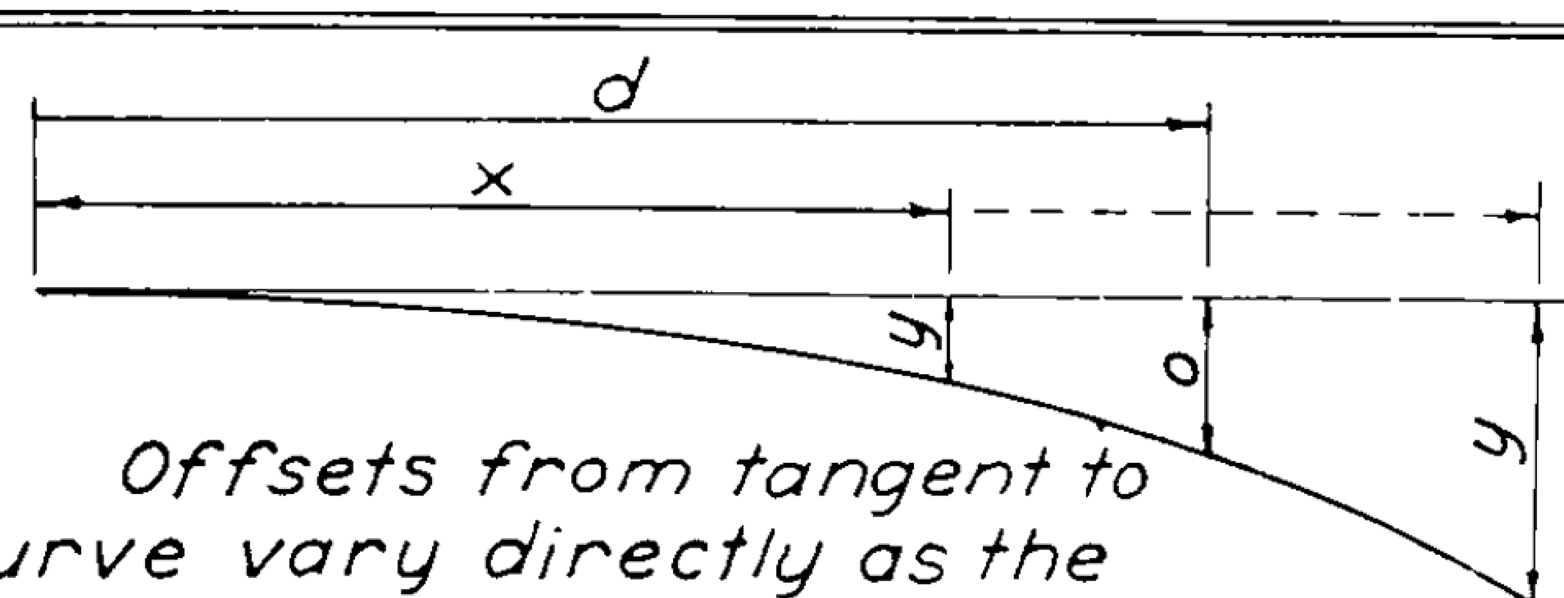
Solution:

$c = \frac{1}{8} \times \frac{22}{2} = 1.375'' = 1\frac{3}{8}''$

$y = 4 \times 1.375\left(\frac{6}{22}\right)^2 = 0.409'' = \frac{13}{32}''$

SYMMETRICAL CROWN

Used for roads and for streets where gutters are same elevation.



Offsets from tangent to curve vary directly as the squares of the tangent distances.

Formula

$d^2 : x^2 = o : y \quad \therefore y = \frac{ox^2}{d^2}$

Example

Given:

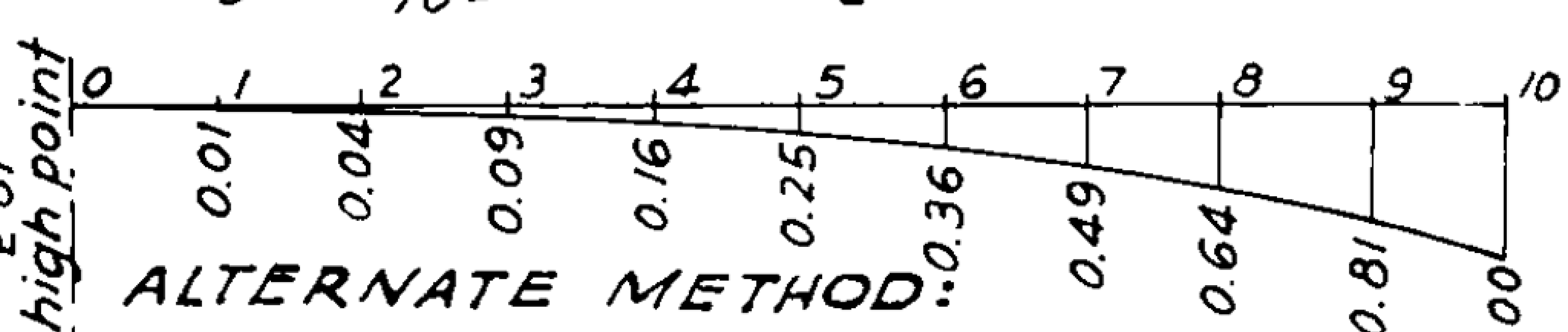
$d = 10'$; $o = 6''$ and $x = 5'$

Required:

y

Solution:

$y = \frac{6 \times 5^2}{10^2} = 1.50'' = 1\frac{1}{2}''$



ALTERNATE METHOD:

Divide the distance from ℄ or high point to edge of pavement into 10 equal spaces. Multiply figures in chart by total crown to get ordinates from crown elevation to pavement surface for points shown.

Example

Given:

Total crown = 6"

Required:

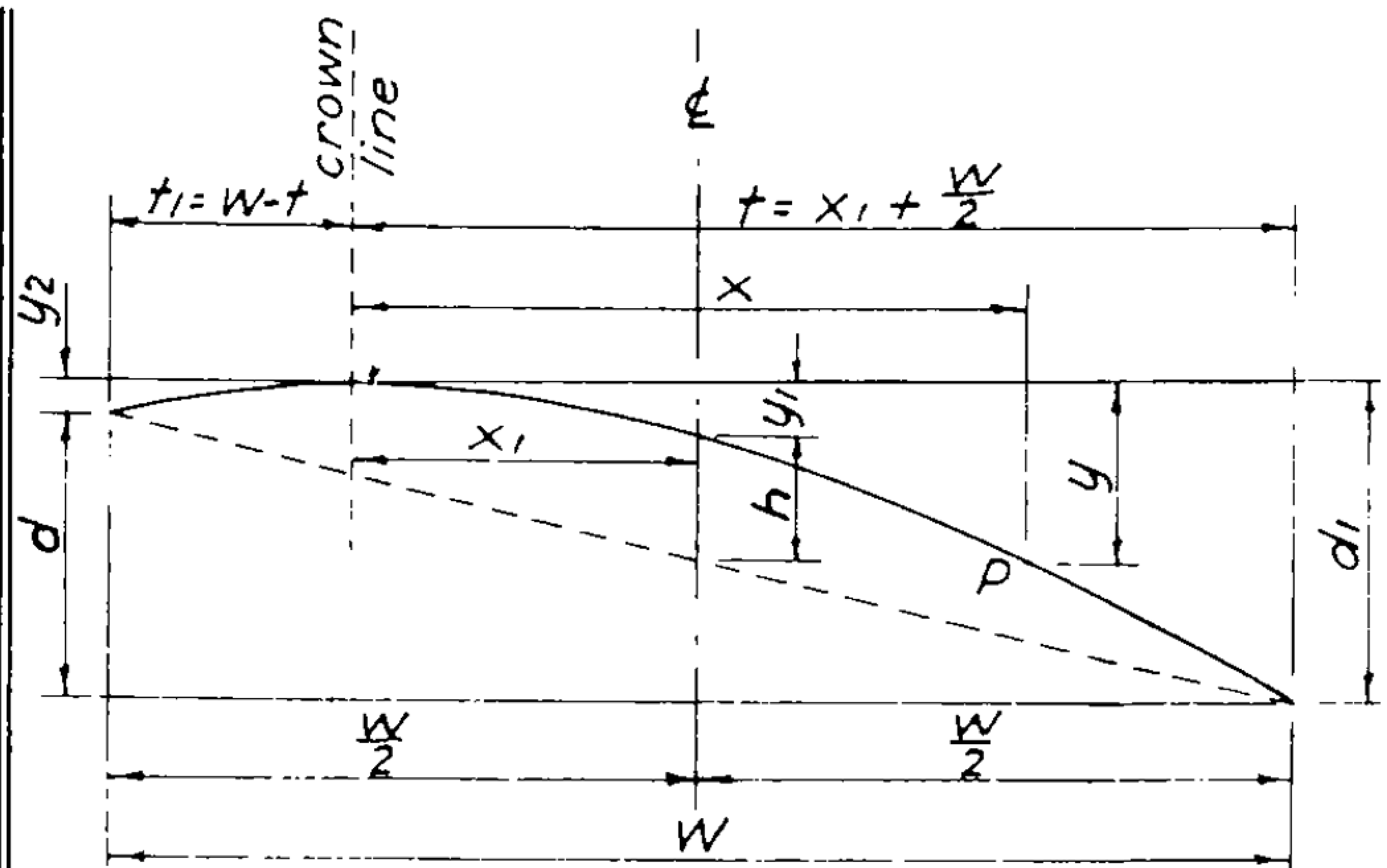
Ordinates at 5th and 8th points

Solution:

Ordinate at 5th point = $0.25 \times 6 = 1.50'' = 1\frac{1}{2}''$

Ordinate at 8th point = $0.64 \times 6 = 3.84'' = 3\frac{13}{16}''$

ORDINATES-ANY PARABOLIC CURVE



Formulas

$x_1 = \frac{dW}{8h}$; $y_1 = \frac{d^2}{16h}$; $d_1 = \frac{d}{2} + h + y_1$; $y = \frac{d_1 x^2}{t^2}$

$y_2 = d_1 - d$; $t = x_1 + \frac{W}{2}$; $t_1 = W - t$

Example

Given:

$h = 0.5'$; $W = 40'$; $d = 0.5'$; $x = 10'$

Required:

x_1; y_1; d_1; y_2; y; t and t_1

Solution:

$x_1 = \frac{0.5 \times 40}{8 \times 0.5} = 5.0'$

$y_1 = \frac{0.5^2}{16 \times 0.5} = 0.0312' = 0.375'' = \frac{3}{8}''$

$d_1 = \frac{0.5}{2} + 0.5 + 0.0312 = 0.7812' = 9.375'' = 9\frac{3}{8}''$

$y_2 = 0.7812 - 0.5 = 0.2812' = 3.375'' = 3\frac{3}{8}''$

$t = 5.0 + \frac{40}{2} = 25.0'$

$y = \frac{0.7812 \times 10^2}{25^2} = 0.125' = 1\frac{1}{2}''$

$t_1 = 40 - 25 = 15'$

UNSYMMETRICAL CROWN

Used for city streets where conditions necessitate different gutter elevations. If slope per foot is over $\frac{1}{2}''$, a stepped curb or retaining wall should be used on uphill side of street.

Also used for off-center crowns on 3-lane roads to provide symmetrical crown for future 4 lanes.

Also used for transition onto superelevated curves.

ROADS-PARABOLIC CROWN ORDINATES-2

ORDINATES FROM GRADE TANGENT TO SURFACE FOR EACH FOOT OF WIDTH

SURFACE WIDTH OF STREET OR ROAD

20'

½":1' Crown		
1	1/16"	.004'
2	3/16"	.017'
3	7/16"	.037'
4	13/16"	.067'
5	1 1/4"	.104'
6	1 13/16"	.150'
7	2 7/16"	.204'
8	3 3/16"	.267'
9	4 1/16"	.337'
10	5"	.417'

3/8":1' Crown		
1	1/16"	.003'
2	1/8"	.012'
3	5/16"	.028'
4	5/8"	.050'
5	15/16"	.078'
6	1 3/8"	.112'
7	1 13/16"	.153'
8	2 3/8"	.200'
9	3 1/16"	.253'
10	3 3/4"	.312'

¼":1' Crown		
1	0"	.002'
2	1/8"	.008'
3	1/4"	.019'
4	3/8"	.033'
5	5/8"	.052'
6	7/8"	.075'
7	1 1/4"	.102'
8	1 5/8"	.133'
9	2 1/4"	.190'
10	2 1/2"	.208'

22'

3/8":1' Crown		
1	1/16"	.003'
2	1/8"	.011'
3	5/16"	.026'
4	9/16"	.045'
5	7/8"	.071'
6	1 1/4"	.102'
7	1 11/16"	.139'
8	2 3/16"	.182'
9	2 3/4"	.230'
10	3 7/16"	.284'
11	4 1/8"	.344'

¼":1' Crown		
1	0"	.002'
2	1/8"	.008'
3	3/16"	.017'
4	3/8"	.030'
5	9/16"	.047'
6	13/16"	.068'
7	1 1/8"	.093'
8	1 7/16"	.121'
9	1 13/16"	.153'
10	2 1/4"	.189'
11	2 3/4"	.229'

1/8":1' Crown		
1	0"	.001'
2	1/16"	.004'
3	1/8"	.009'
4	3/16"	.015'
5	5/16"	.024'
6	7/16"	.034'
7	9/16"	.046'
8	3/4"	.061'
9	15/16"	.077'
10	1 1/8"	.095'
11	1 3/8"	.115'

34'

¼":1' Crown		
1	0"	.003'
2	1/16"	.005'
3	1/8"	.011'
4	1/4"	.020'
5	3/8"	.031'
6	1/2"	.044'
7	3/4"	.060'
8	15/16"	.078'
9	1 3/16"	.099'
10	1 1/2"	.123'
11	1 3/4"	.148'
12	2 1/8"	.176'
13	2 1/2"	.207'
14	2 7/8"	.240'
15	3 5/16"	.276'
16	3 3/4"	.314'
17	4 1/4"	.354'

1/8":1' Crown		
1	0"	.001'
2	0"	.002'
3	1/16"	.006'
4	1/8"	.010'
5	3/16"	.015'
6	1/4"	.022'
7	3/8"	.030'
8	7/16"	.039'
9	5/8"	.050'
10	3/4"	.061'
11	7/8"	.074'
12	1 1/16"	.088'
13	1 1/4"	.104'
14	1 7/16"	.120'
15	1 5/8"	.138'
16	1 7/8"	.157'
17	2 1/8"	.177'

40'

¼":1' Crown		
1	0"	.000'
2	1/16"	.004'
3	1/8"	.009'
4	3/16"	.017'
5	5/16"	.026'
6	7/16"	.038'
7	5/8"	.051'
8	13/16"	.067'
9	1"	.084'
10	1 1/4"	.104'
11	1 1/2"	.126'
12	1 13/16"	.150'
13	2 1/8"	.176'
14	2 7/16"	.204'
15	2 13/16"	.234'
16	3 3/16"	.267'
17	3 5/8"	.301'
18	4 1/16"	.338'
19	4 1/2"	.376'
20	5"	.417'

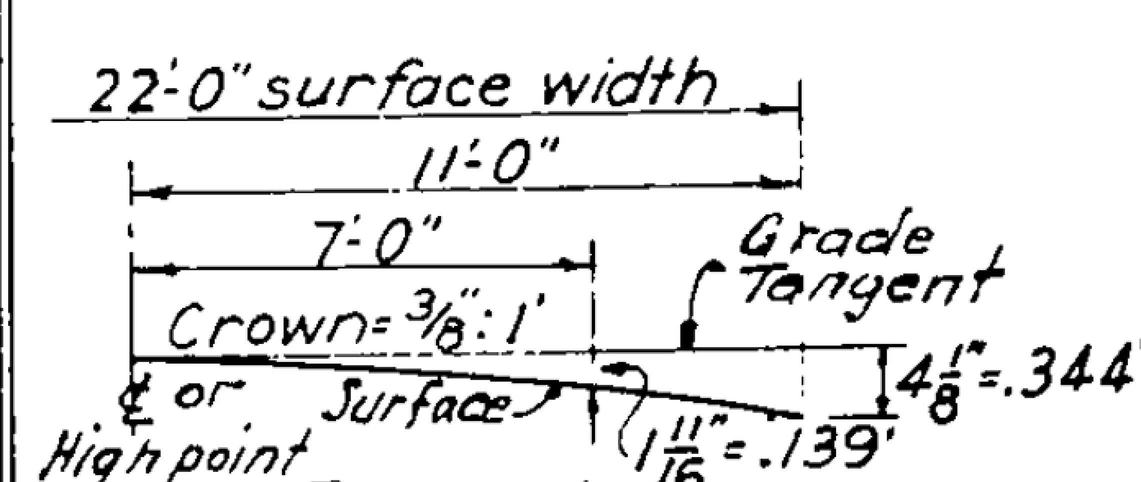
1/8":1' Crown		
1	0"	.001'
2	0"	.002'
3	1/16"	.005'
4	1/8"	.008'
5	3/16"	.013'
6	1/4"	.019'
7	5/16"	.026'
8	3/8"	.033'
9	1/2"	.042'
10	5/8"	.052'
11	3/4"	.063'
12	7/8"	.075'
13	1 1/16"	.088'
14	1 1/4"	.102'
15	1 3/8"	.117'
16	1 5/8"	.133'
17	1 13/16"	.151'
18	2"	.169'
19	2 1/4"	.188'
20	2 1/2"	.208'

44'

1/8":1' Crown		
1	0"	.000'
2	0"	.002'
3	1/16"	.004'
4	1/8"	.008'
5	1/8"	.012'
6	3/16"	.017'
7	1/4"	.023'
8	3/8"	.030'
9	7/16"	.038'
10	9/16"	.047'
11	11/16"	.057'
12	13/16"	.068'
13	15/16"	.080'
14	1 1/8"	.093'
15	1 5/16"	.107'
16	1 7/16"	.121'
17	1 5/8"	.137'
18	1 13/16"	.153'
19	2 1/16"	.171'
20	2 1/4"	.189'
21	2 1/2"	.209'
22	2 3/4"	.229'

60'

1/8":1' Crown		
1	0"	.000'
2	0"	.001'
3	1/16"	.003'
4	1/16"	.006'
5	1/8"	.009'
6	1/8"	.012'
7	3/16"	.017'
8	1/4"	.022'
9	5/16"	.028'
10	7/16"	.035'
11	1/2"	.042'
12	5/8"	.050'
13	11/16"	.059'
14	13/16"	.068'
15	15/16"	.078'
16	1 1/16"	.089'
17	1 3/16"	.100'
18	1 3/8"	.112'
19	1 1/2"	.125'
20	1 11/16"	.139'
21	1 13/16"	.153'
22	2"	.168'
23	2 3/16"	.184'
24	2 3/8"	.200'
25	2 5/8"	.217'
26	2 13/16"	.235'
27	3 1/16"	.253'
28	3 1/4"	.272'
29	3 1/2"	.292'
30	3 3/4"	.312'

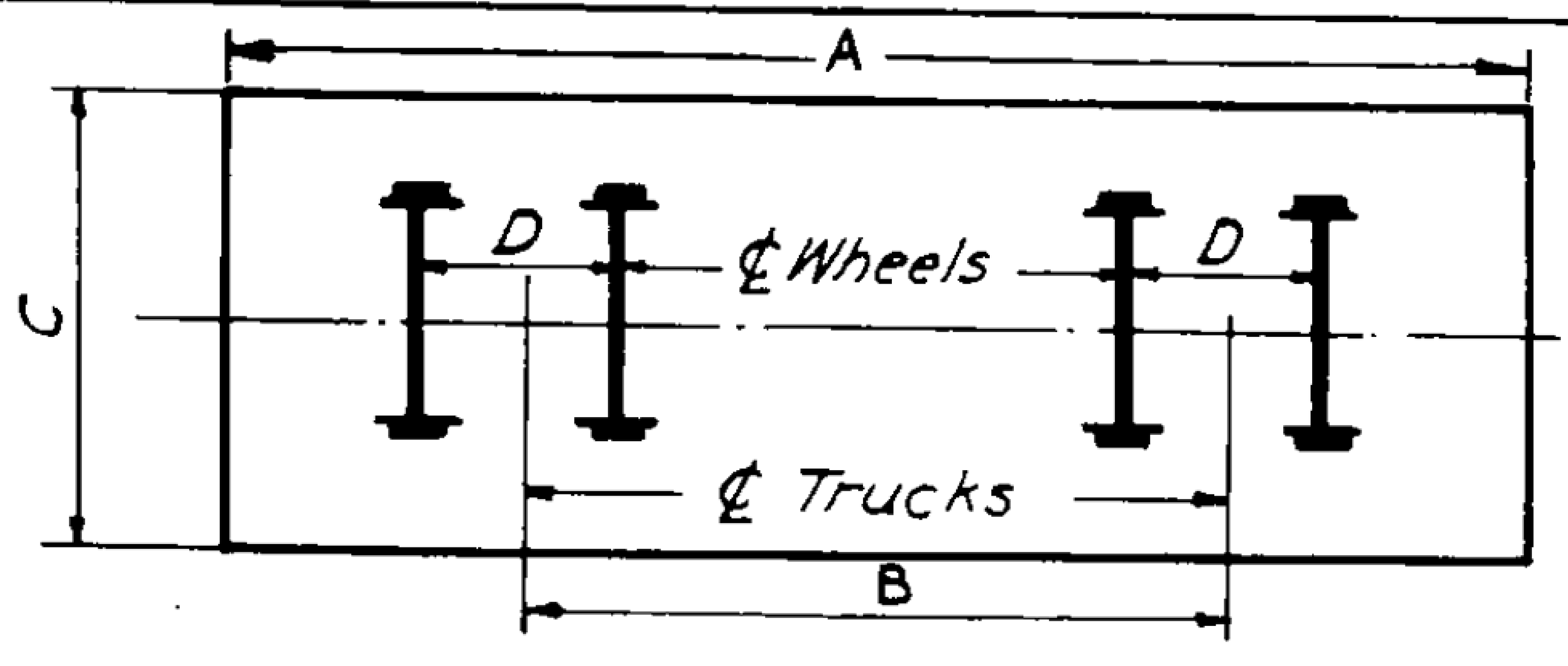


Example

RAILROADS - GENERAL

TABLE A - SPUR AND SIDING DESIGN DATA.

HORIZONTAL CURVES (See pg. 3-46 to 3-58 incl. for curve data, funtions of 1° curve, etc.)	MAXIMUM DEGREE OF CURVE. Recommended general practice 14° to 16° Road Engines 18° Steam Switch Engines 23° Diesel Switch Engines (150' Rad.) 38°56' Freight Cars 30° Desired. " " 60° Max. (100' Rad.). Passenger Cars 12° Desired. " " 18° Max. Recent models of Diesel Switch Engines can use a 60° (100' Radius) curve.
REVERSE HORIZONTAL CURVES	A — Provide a tangent distance "A" greater than a car length.
SUPERELEVATION	On curves over 8° use 1/2" or use Table A - Pg. 4-05.
VERTICAL CURVES	50' minimum length - use 200' if space permits.
GRADES	Maximum for Road Engines - use 1½%; for Diesel Switch Engines - use 2%. For unavoidable grades greater than above consult using Railroad. A Diesel Switch Engine can push several cars up a 4% grade, but such grades give poor operating results.
TURNOUTS	If avoidable do not locate turnouts on superelevated curves. All turnouts from any main line to be #10 Min. Turnouts from ladder tracks to be #8 Min. Turnouts in yards, or from spurs or sidings used by a Road Engine to be #8 Min.; by a Switch Engine #6 Min.
OVERHEAD CLEARANCES	16'-0" minimum - 22'-0" if men are working on top of cars. Use ticklers if clearance is less than 22'-0". See Fig. A page 4-02.
SIDE CLEARANCES	See Fig. A, page 4-02.
TIE SPACING	Use 21" if Road Engines are to be used. 2'-0" maximum.
RAILS	Minimum weight 90 pounds per yard.
TIE PLATES	Use on curves and on creosoted ties.
GAUGE	4'-8½" on tangents and curves up to 8°. Add 1/8" per 2° over 8° up to Max. of 4'-9¼".



DIAGRAMMATIC PLAN.

DIMENSIONS (WILL VARY ACCORDING TO R.R. STANDARD)	TYPES OF CARS. FREIGHT REFRIGERATOR	MILK	70' MAIL & BAGGAGE	80' PASSENGER
A	42'-8"	50'-1½"	70'-0"	82'-4"
B	31'-6"	34'-0"	52'-0"	59'-6"
C	9'-9"	10'-1½"	10'-0"	10'-0"
D	5'-6"	8'-0"	11'-0"	11'-6"

FIG. B - CAR DIMENSIONS.

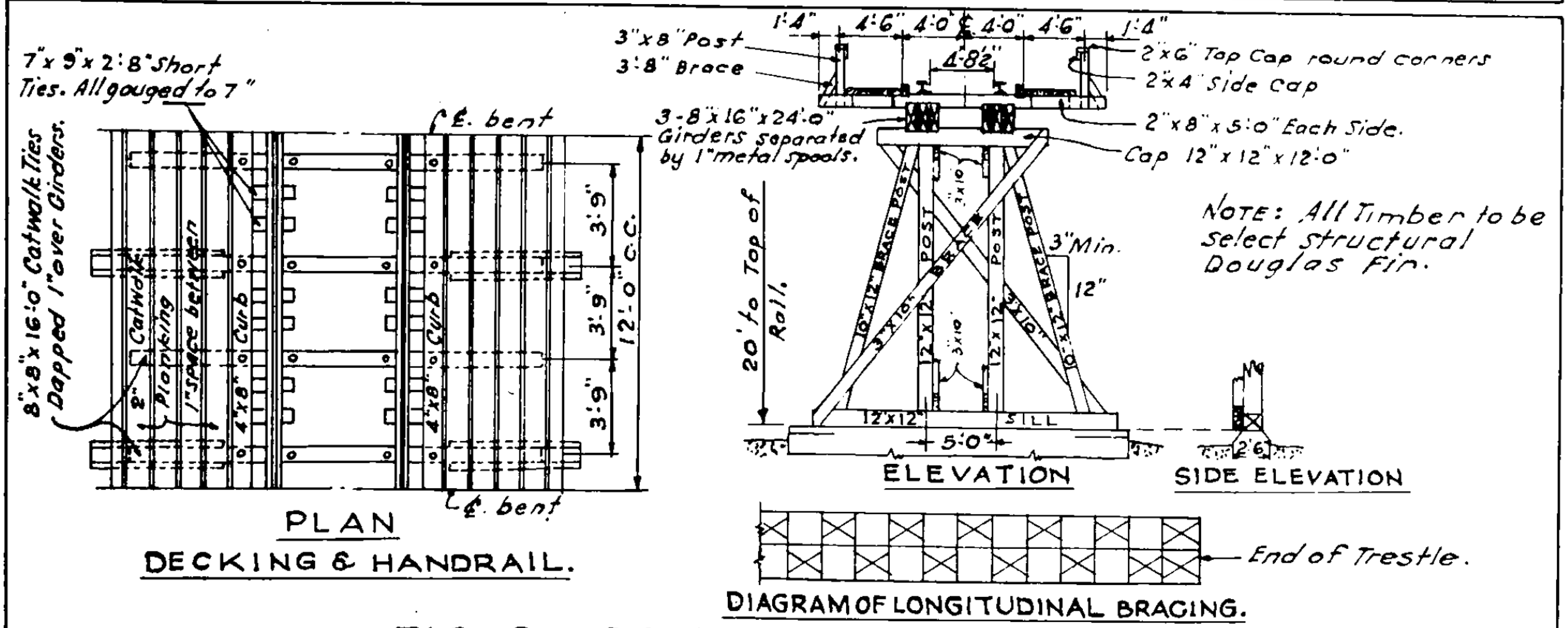
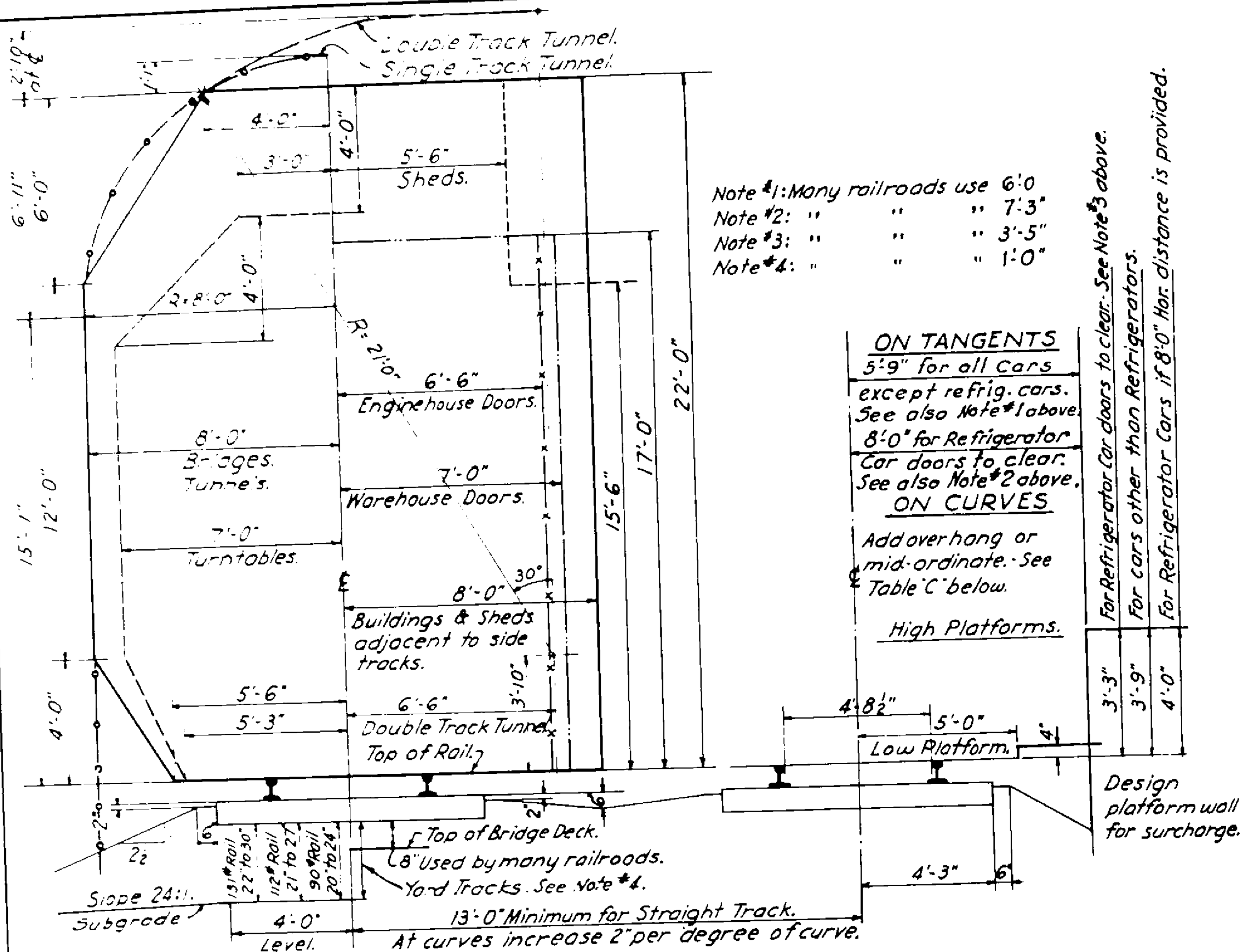


FIG. C - COAL TRESTLE DETAILS.

RAILROADS - CLEARANCE & CROSS SECTION



CLEARANCE & BALLAST SECTION. SIDE UNLOADING PLATFORMS.

FIG. A - TANGENT CLEARANCES.*

Note: Allow for curves as indicated in Table 'C' below.

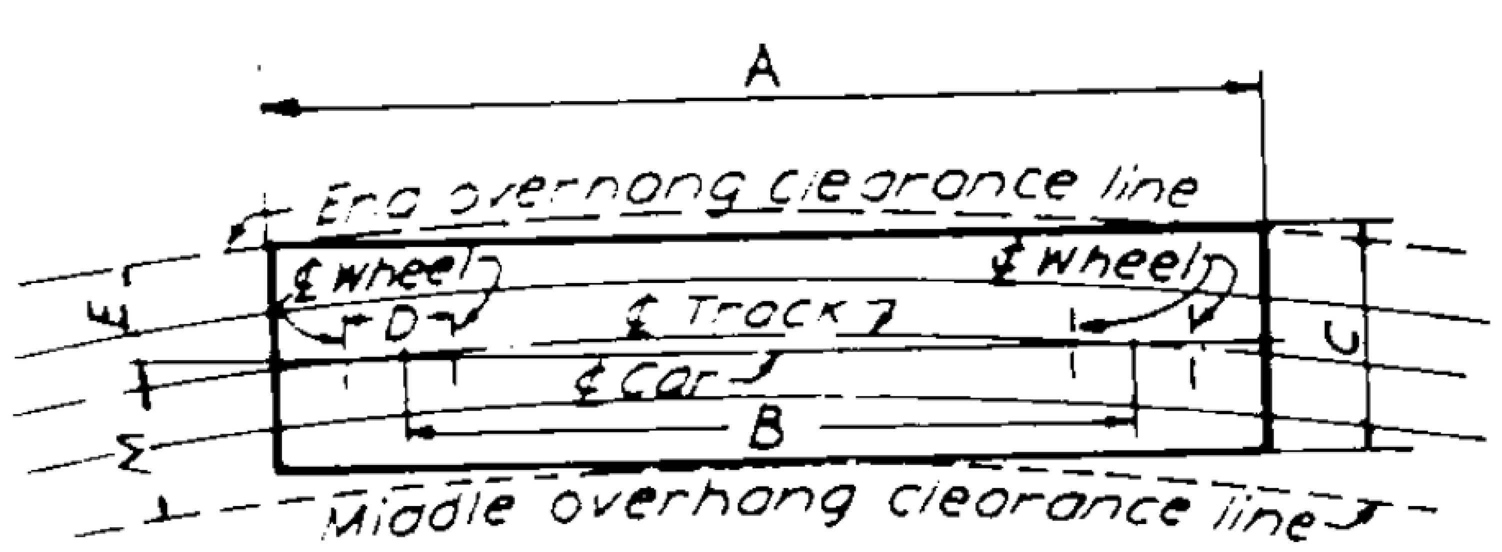


FIG. B - END & MIDDLE OVERHANG.

$$M = R - \sqrt{R^2 - \left[\frac{D^2}{4} + \frac{B^2}{4}\right]} + \frac{C}{2}$$

$$E = \sqrt{(R - M + C)^2 + \frac{A^2}{4}} - R$$

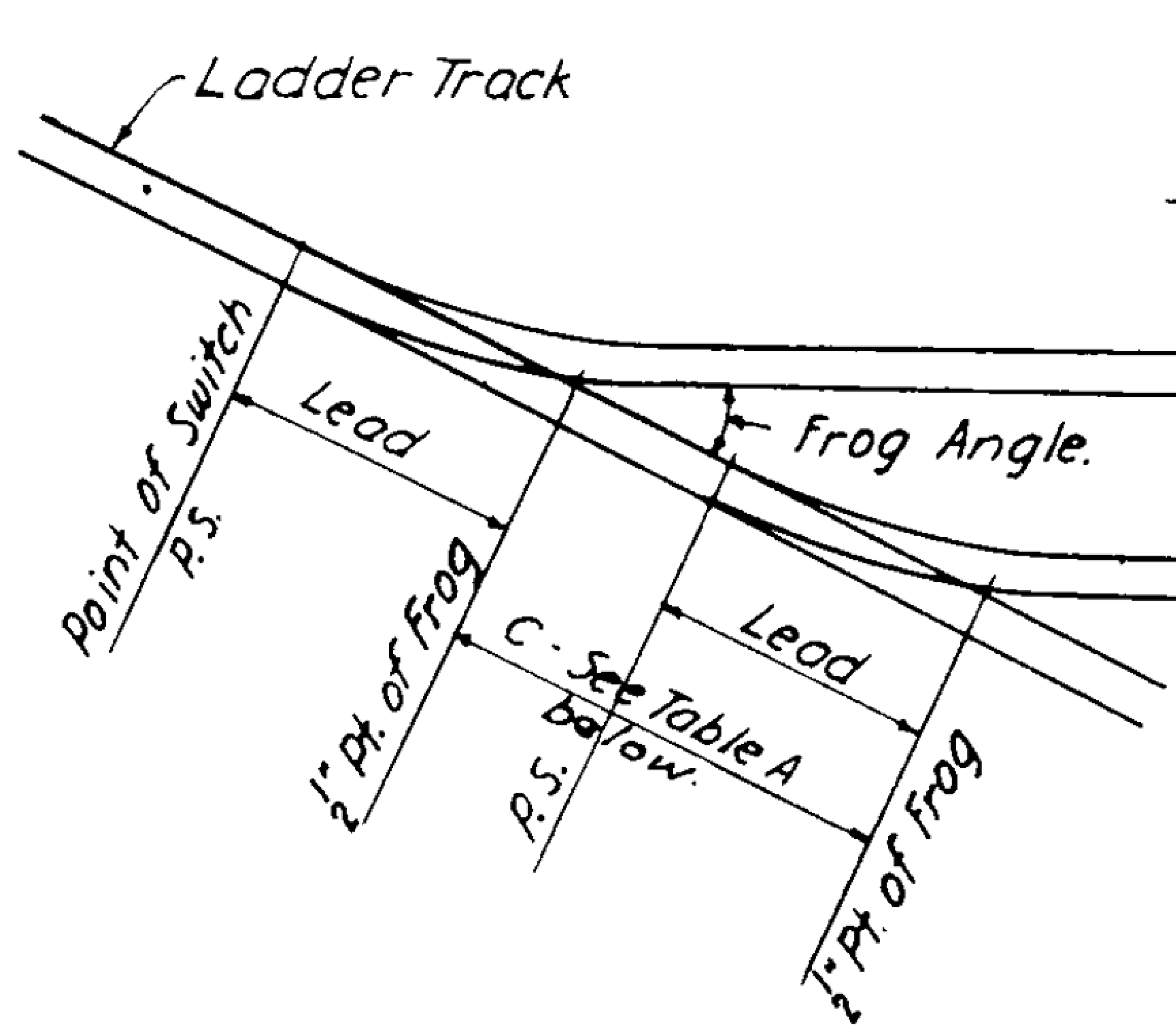
For dimensions of A, B, C and D See Fig. B - pg. 4-01.

TABLE C - ADDITIONAL CLEARANCES IN INCHES AT CURVES FOR CARS SHOWN.

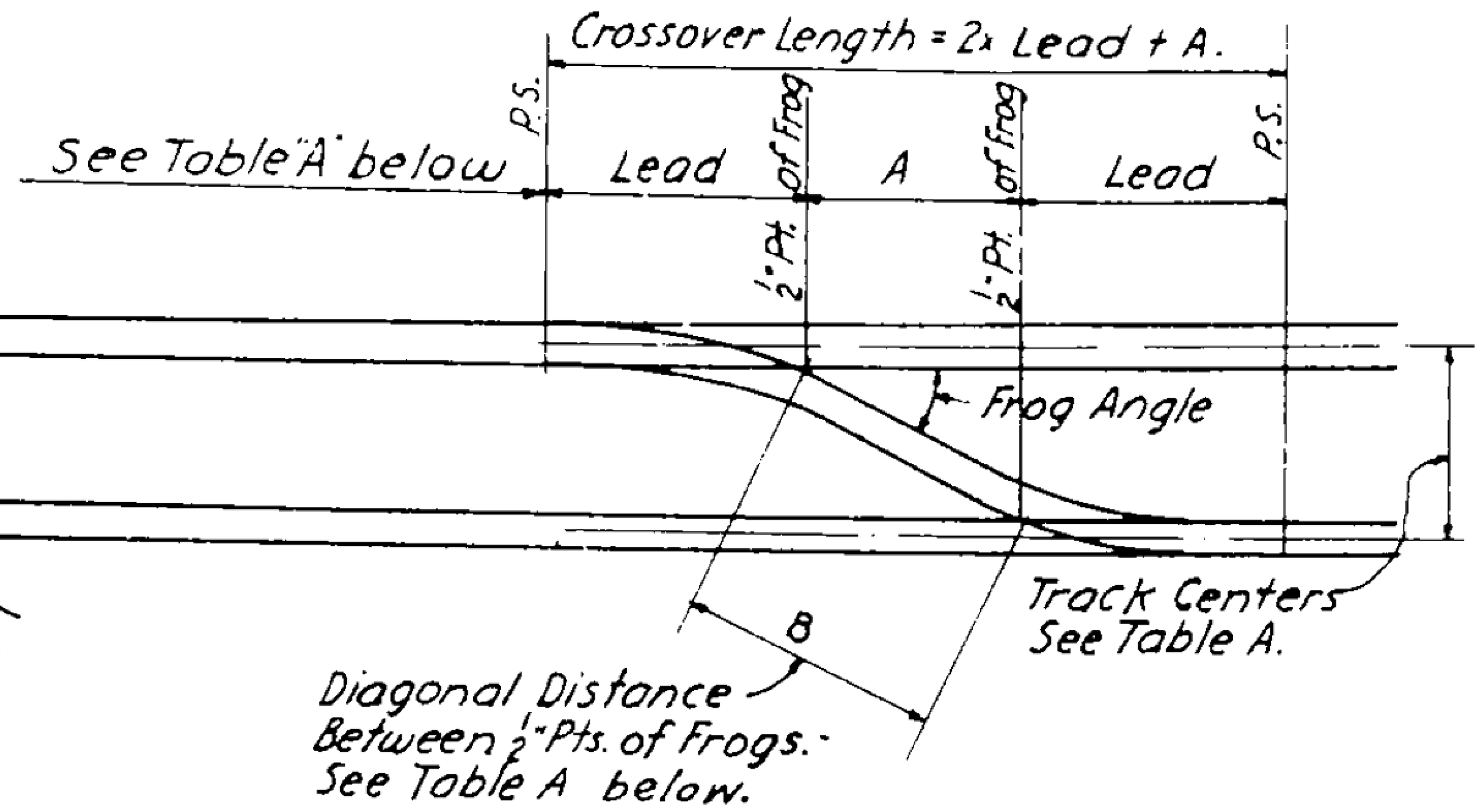
DEGREE OF CURVE	FREIGHT CAR MID.	FREIGHT CAR END	MILK CAR MID.	MILK CAR END	DEGREE OF CURVE	FREIGHT CAR MID.	FREIGHT CAR END	MILK CAR MID.	MILK CAR END
2	1/2	1/2	3/4	3/4	15	4 1/4	3	5	5
3	3/4	1/2	1	1	16	4 1/2	3 1/4	5 1/4	5 1/4
4	1	3/4	1 1/2	1 1/2	17	4 3/4	3 1/2	5 1/2	5 3/4
5	1 1/4	1	1 3/4	1 3/4	18	5	3 3/4	6	6
6	1 1/2	1	2 1/4	2 1/4	19	5 1/4	4	6 1/4	6 1/4
7	1 3/4	1 1/4	2 1/2	2 1/2	20	5 1/2	4	6 1/2	6 1/2
8	2 1/4	1 1/2	2 3/4	2 3/4	21	5 3/4	4 1/4	6 3/4	7
9	2 1/2	1 3/4	3	3	22	6	4 1/2	7	7 1/4
10	2 3/4	2	3 1/4	3 1/2	23	6 1/4	4 3/4	7 1/2	7 1/2
11	3	2 1/4	3 3/4	3 3/4	24	6 1/2	4 3/4	7 3/4	7 3/4
12	3 1/4	2 1/2	4	4	25	6 3/4	5	8	8 1/4
13	3 1/2	2 1/2	4 1/4	4 1/2	28°58'	7 3/4	5 3/4	9 1/4	9 1/4
14	3 3/4	2 3/4	4 1/2	4 3/4	30	8	6	9 1/2	9 3/4

* All data in accord with American Railway Eng. Association (A.R.E.A.) recommendation.

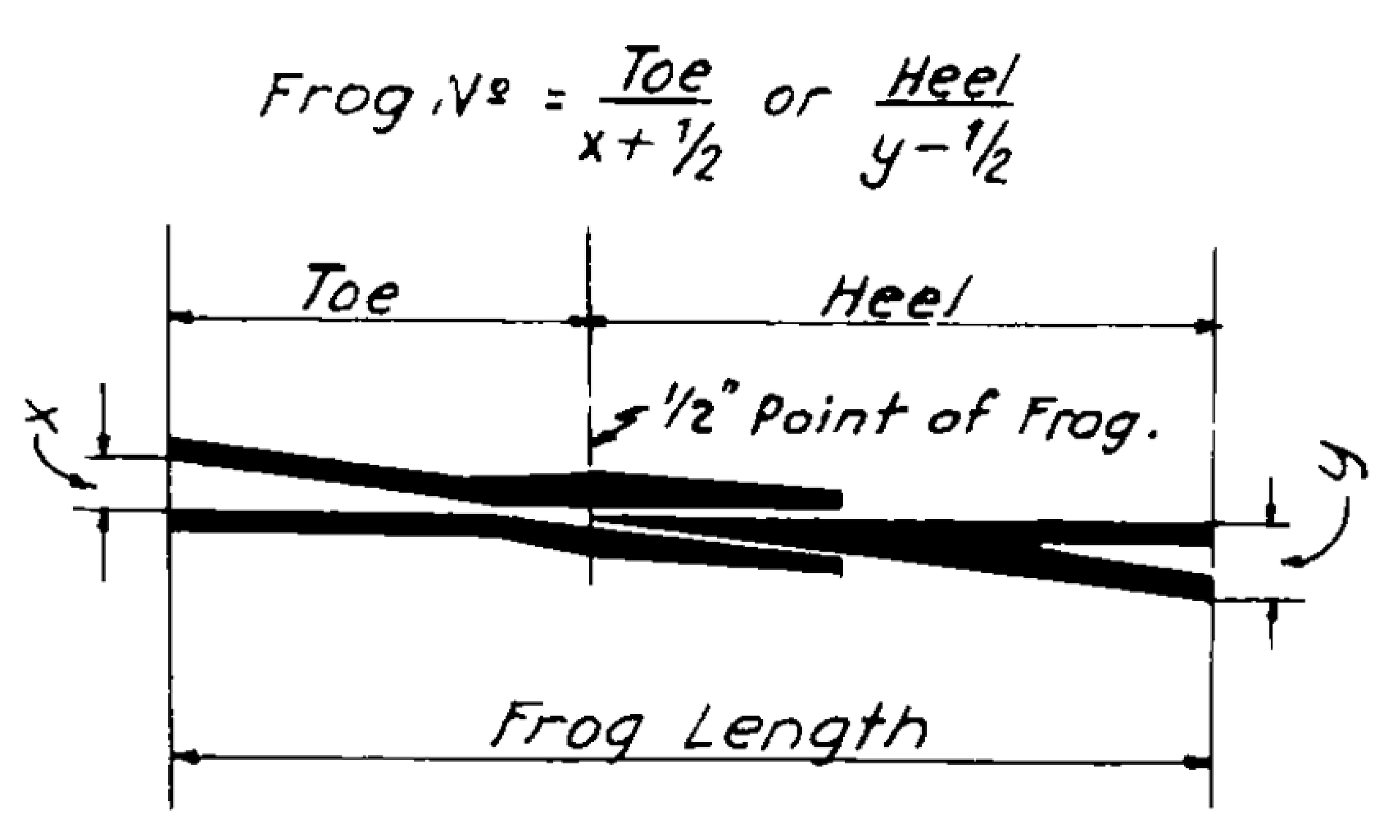
RAILROADS - TURNOUTS & CROSSOVERS



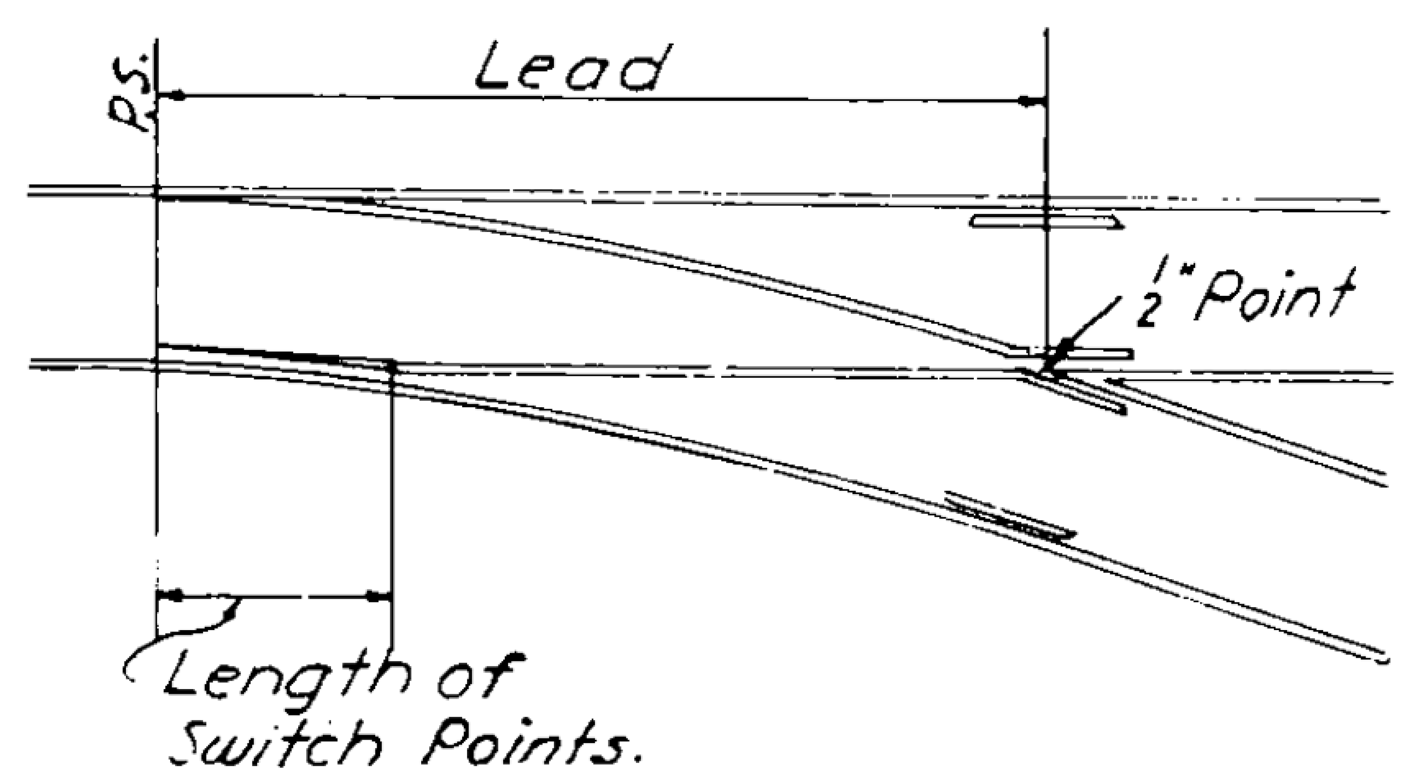
TURNOUT



CROSSOVER



FROG DETAIL



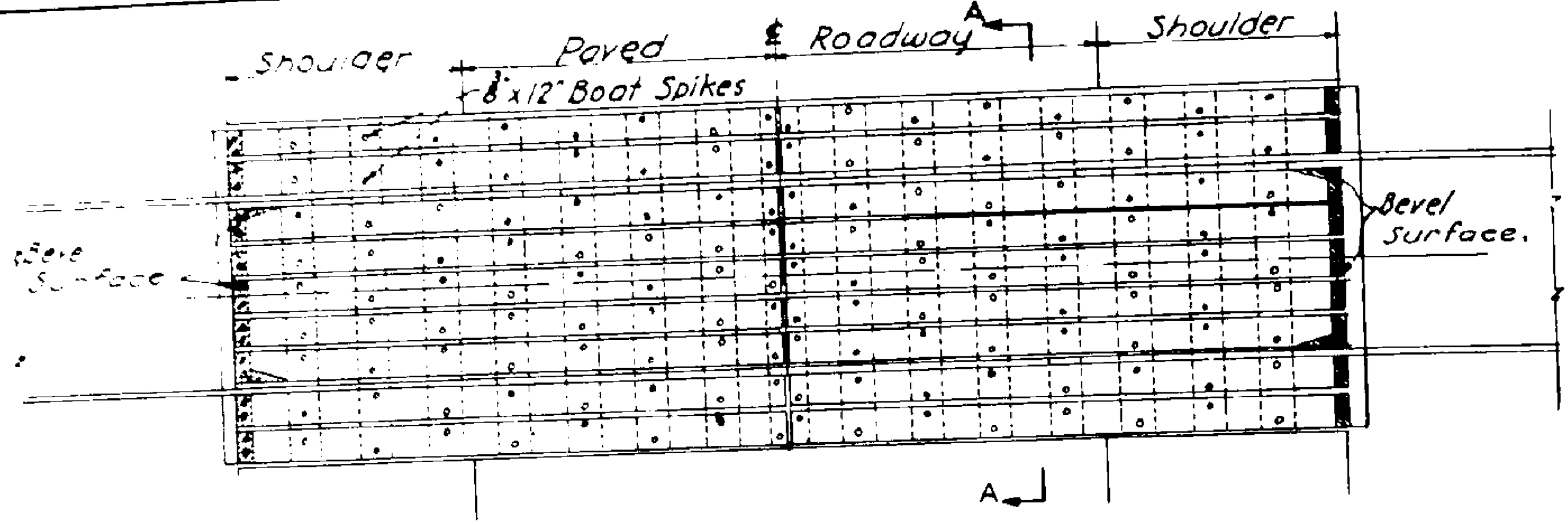
SPLIT-SWITCH TURNOUT

TABLE A - FROGS, SWITCHES, TURNOUTS & CROSSOVERS.

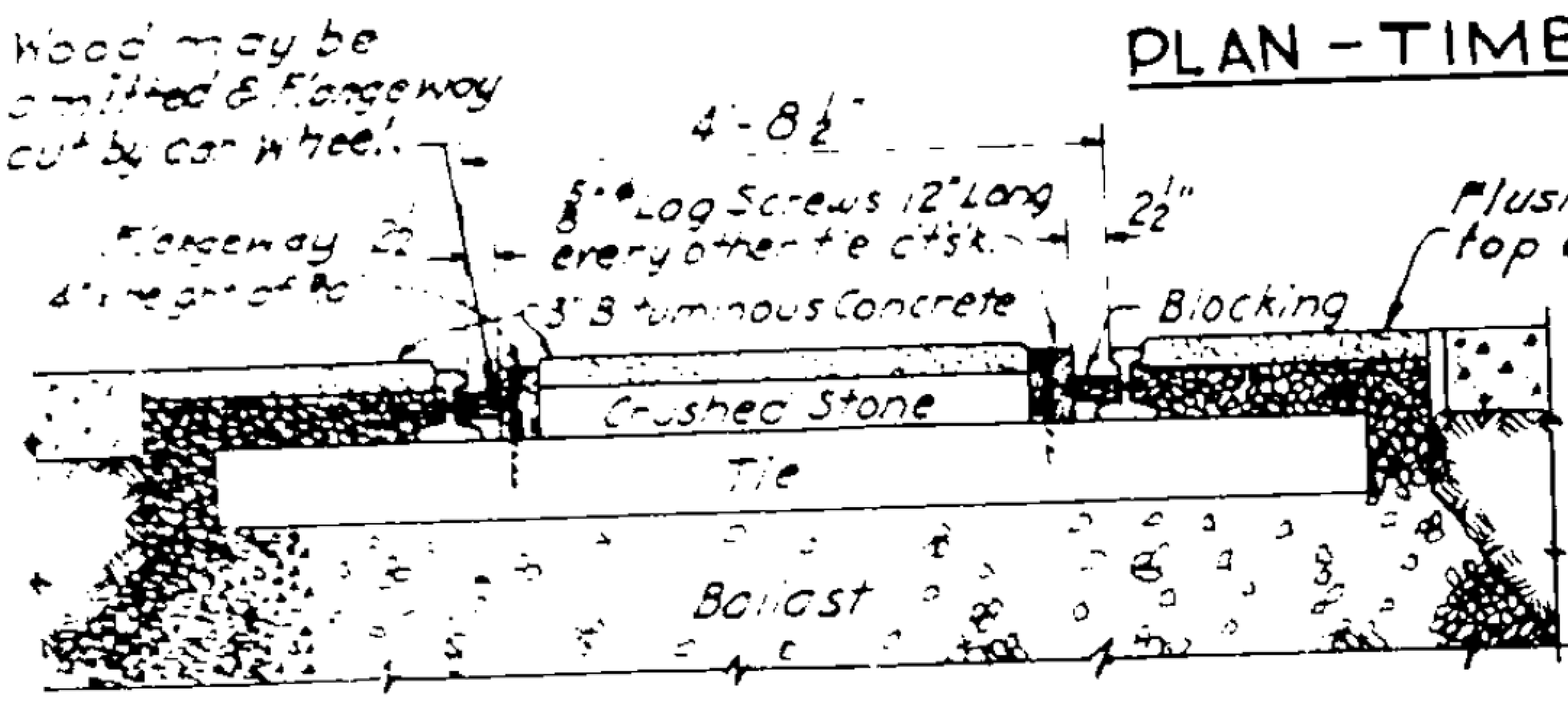
FROG No	FROGS		SWITCHES		TURNOUTS AND CROSSOVERS — DISTANCE IN FEET BETWEEN CENTER LINES OF TRACKS - GAGE - 4'-8½"																Q*	
	FROG ANGLE	FROG LENGTH	LENGTH OF SWITCH POINTS	LEAD DISTANCE FROM PT. OF SWITCH TO 1/2" PT. OF FROG	12'-0"			13'-0"			14'-0"			16'-0"			18'-0"				
					A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	C
6	9°-31'-38"	11'-4½"	11'-0"	48.19	14.50	16.23	72.50	20.46	22.07	78.54	26.42	28.00	84.58	38.33	39.96	96.67	50.24	51.97	108.75	.596	.604
7	8°-10'-16"	14'-7½"	16'-6"	61.28	17.07	18.57	84.43	24.04	25.43	91.47	31.00	32.36	98.50	44.93	46.33	112.57	58.85	60.33	126.14	.696	.704
8	7°-09'-10"	15'-5"	16'-6"	67.14	19.63	20.93	96.37	27.60	28.82	104.40	35.57	36.76	112.44	51.51	52.73	128.50	67.45	68.75	144.56	.797	.804
9	6°-21'-35"	16'-3"	16'-6"	72.73	22.17	23.34	108.33	31.14	32.21	117.36	40.12	41.18	126.39	58.07	59.16	144.44	76.02	77.17	162.50	.898	.903
10	5°-43'-29"	17'-10½"	16'-6"	77.61	24.71	25.76	120.30	34.68	35.65	130.33	44.66	45.61	140.35	64.61	65.59	160.40	84.56	85.60	180.45	.998	1.003
12	4°-46'-19"	20'-4"	22'-0"	97.25	29.76	30.64	144.25	41.73	42.54	156.27	53.71	54.51	168.29	77.67	78.49	192.33	101.62	102.49	216.37	1.198	1.202
14	4°-05'-27"	23'-7"	22'-0"	107.33	34.80	35.54	168.21	48.78	49.49	182.23	62.76	63.44	196.25	90.73	91.43	224.28	118.69	119.43	252.32	1.398	1.402
16	3°-34'-47"	26'-0"	30'-0"	131.36	39.82	40.47	192.19	55.81	56.42	208.21	71.79	72.39	224.23	103.76	104.37	256.26	135.73	136.38	288.29	1.598	1.602
18	3°-10'-56"	29'-3"	30'-0"	141.14	44.85	45.44	216.17	62.84	63.38	234.19	80.82	81.36	252.20	116.79	117.33	288.23	152.76	153.34	324.26	1.798	1.802

*Note: Columns A & C under Q give the amounts to add to Tabular figures for every tenth (0.1) of a foot increase in distance between tracks.

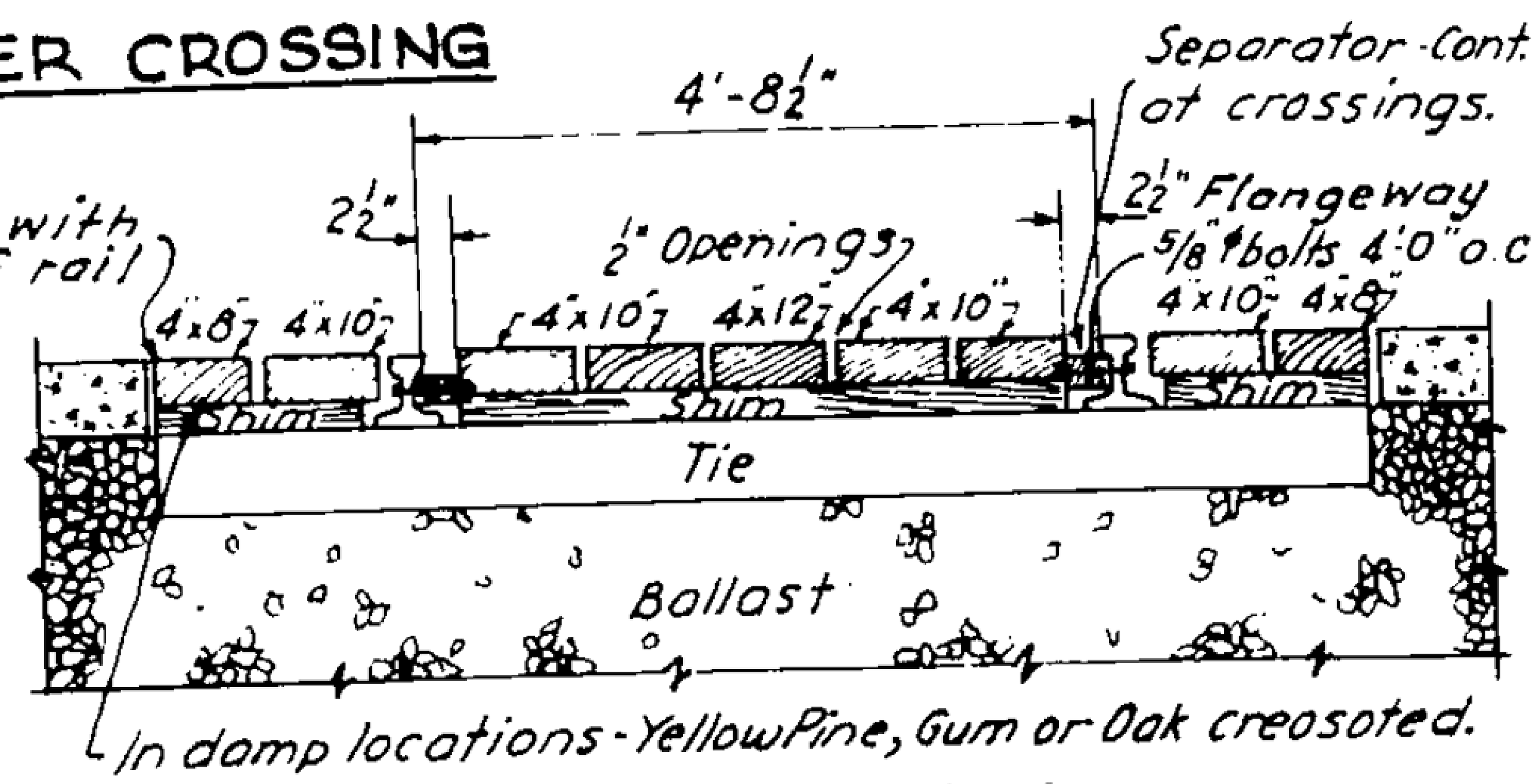
RAILROADS - GRADE CROSSINGS & UNLOADING PLATFORMS



PLAN - TIMBER CROSSING

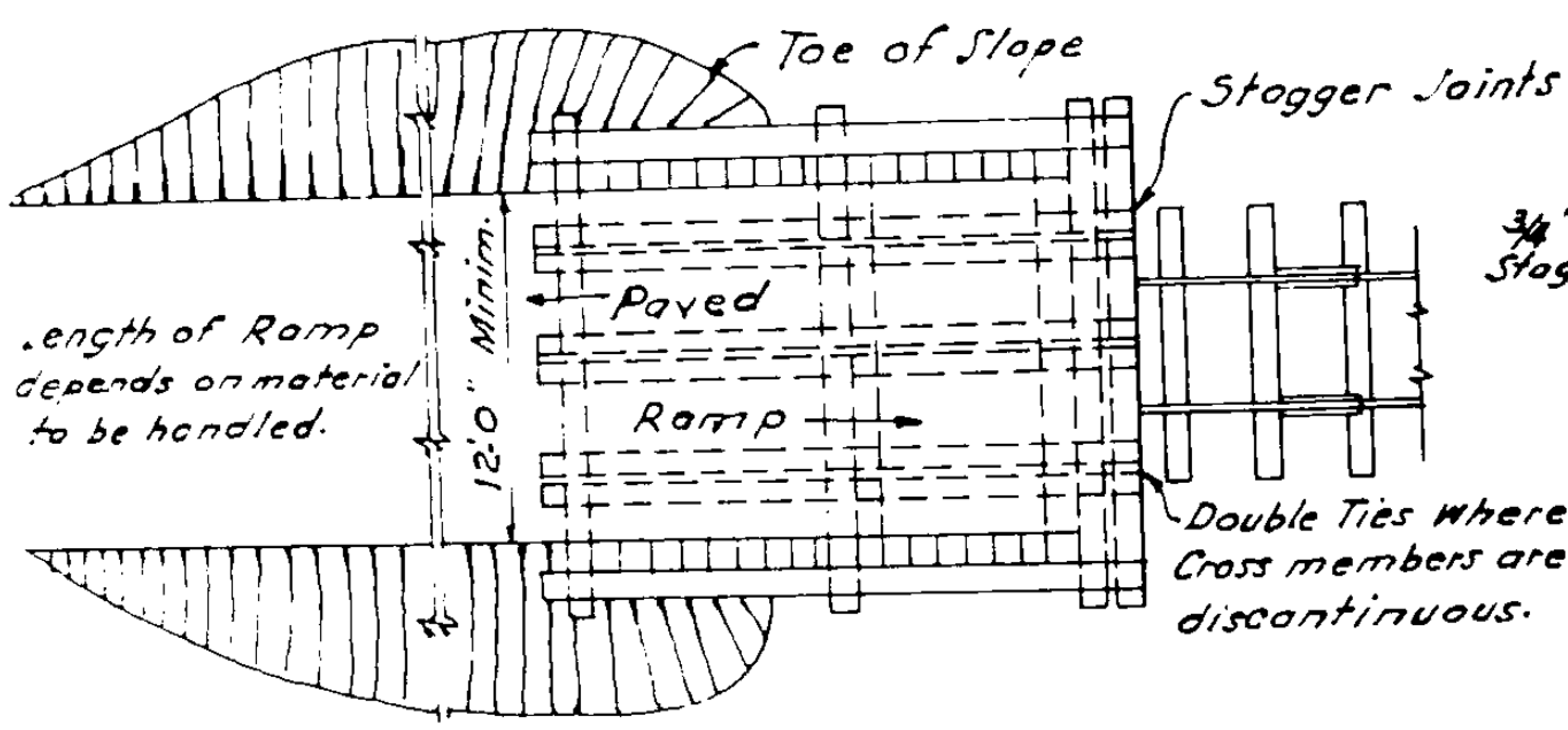


SECTION SHOWING BITUMINOUS CONC. CROSSING.

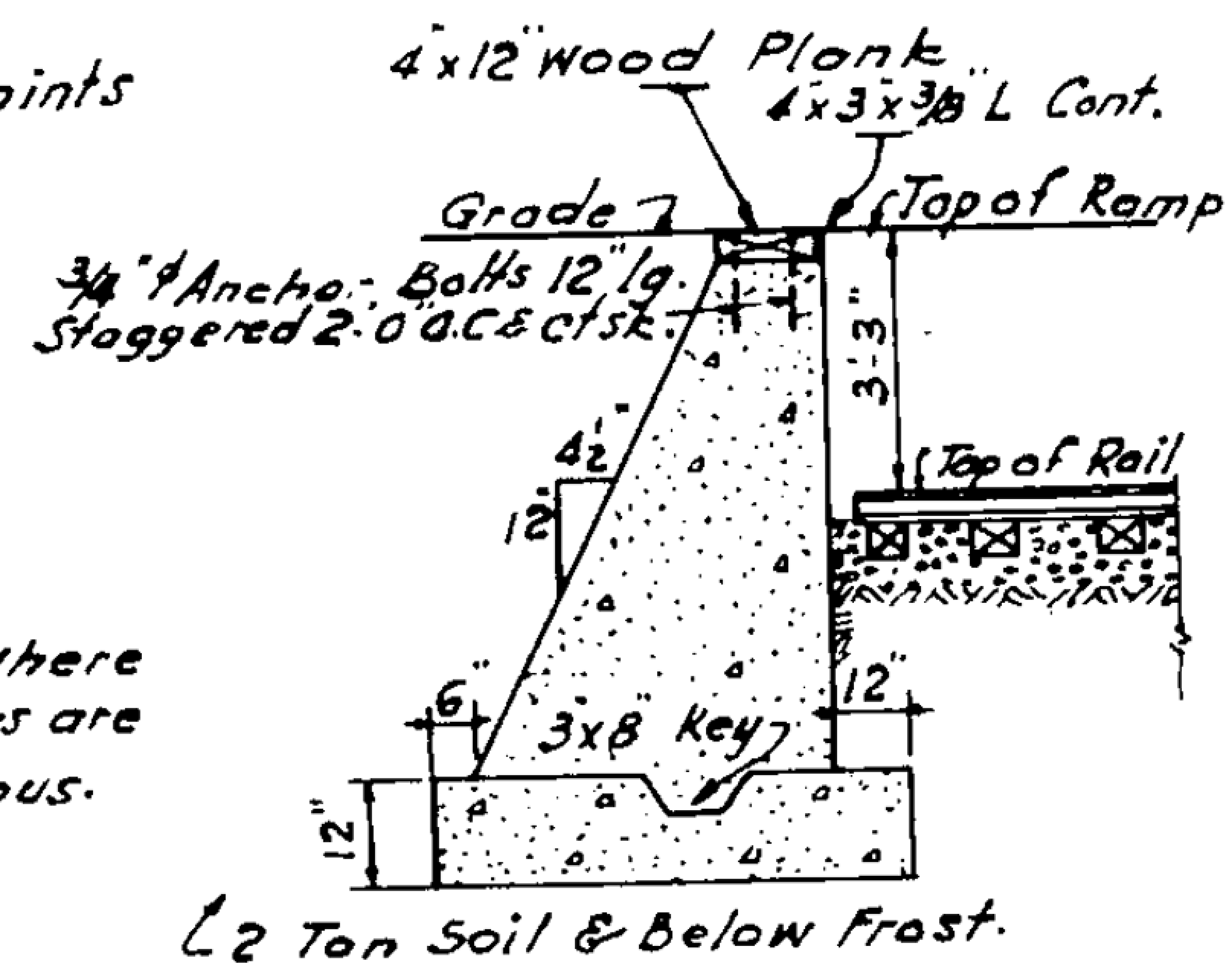


SECTION A-A.

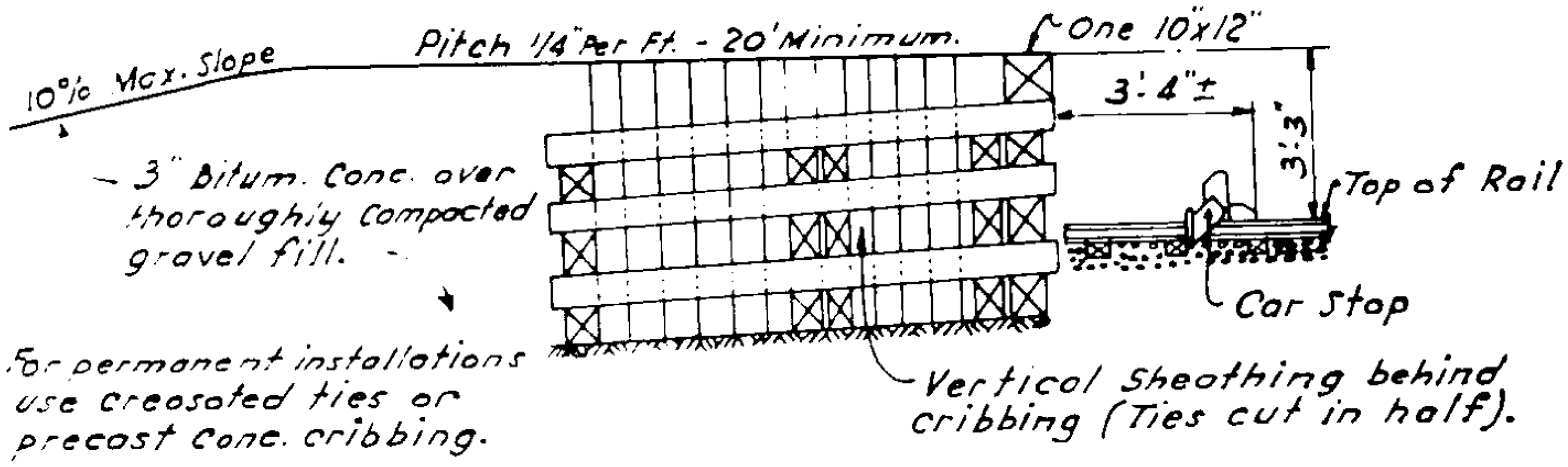
FIG. A - RAILROAD CROSSING CONSTRUCTION.



PLAN



CONCRETE RETAINING WALL ALTERNATE FOR END OF RAMP.



ELEVATION

FIG. B - END UNLOADING PLATFORM DETAILS.

RAILROADS-SUPERELEVATION & ACCESSORIES

TABLE A-SUPERELEVATION OF OUTER RAIL IN INCHES, STANDARD GAGE. *

(Elevation of center of outer rail above center of inner rail.)

Deg. of curve	Velocity in miles per hour 15	20	25	30	35	40	45	50	55	60	65	70
1	1/8	1/4	3/8	5/8	7/8	1-1/8	1-3/8	1-3/4	2-1/8	2-1/2	2-7/8	3-3/8
2	1/4	1/2	7/8	1-1/4	1-3/4	2-1/4	2-3/4	3-1/2	4-1/8	5	5-7/8	6-3/4
3	1/2	7/8	1-1/4	1-7/8	2-1/2	3-1/4	4-1/4	5-1/8	6-1/4	7-1/2	8-3/4	10-1/8
4	5/8	1-1/8	1-3/4	2-1/2	3-3/8	4-3/8	5-5/8	6-7/8	8-3/8	10	....	....
5	3/4	1-3/8	2-1/8	3-1/8	4-1/4	5-1/2	7	8-5/8	....	....	....	....
6	7/8	1-5/8	2-5/8	3-3/4	5-1/8	6-5/8	8-3/8	....	....	....	....	....
7	1-1/8	1-7/8	3	4-3/8	5-7/8	7-3/4	....	....	....	....	....	....
8	1-1/4	2-1/4	3-1/2	5	6-3/4	8-7/8	....	....	....	....	....	....
9	1-3/8	2-1/2	3-7/8	5-5/8	7-5/8	....	....	....	....	....	....	....
10	1-1/2	2-3/4	4-1/4	6-1/4	8-1/2	....	....	....	....	....	....	....
11	1-3/4	3	4-3/4	6-7/8			....	....	....	....	....	....
12	1-7/8	3-1/4	5-1/8	7-1/2	....	....	....	....	....	....	....	....
13	2	3-5/8	5-5/8	8-1/8	....	....	....	....	....	....	....	....
14	2-1/8	3-7/8	6	8-3/4	....	....	....	....	....	....	....	....
15	2-3/8	4-1/8	6-1/2	9-1/4	....	....	....	....	....	....	....	....

For mixed speed traffic, subtract 3"; no superelevation where less than 3" shown.

FIG. D-"HAYES" HINGE TYPE DERAIL.**

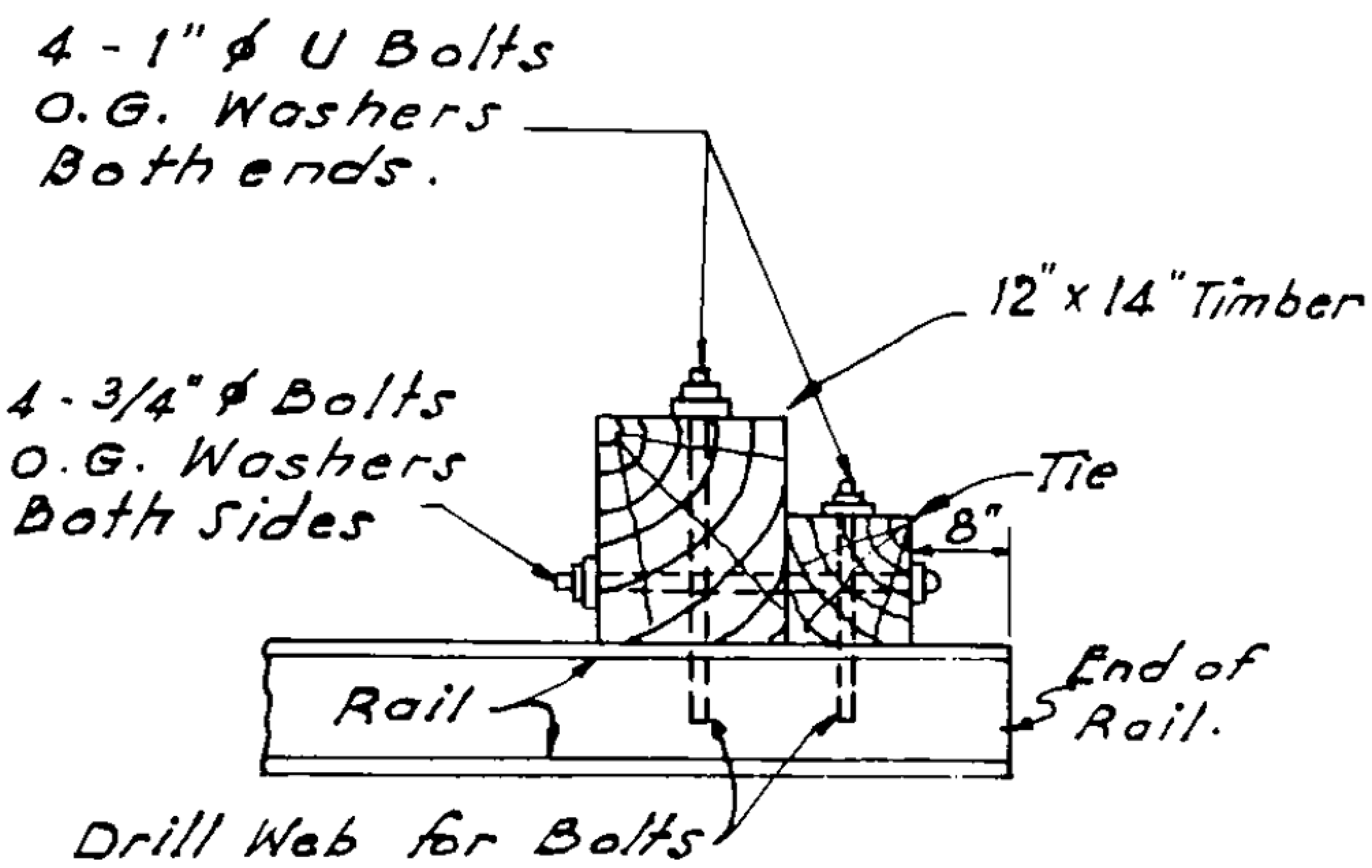


FIG. B - TIMBER WHEEL STOP.

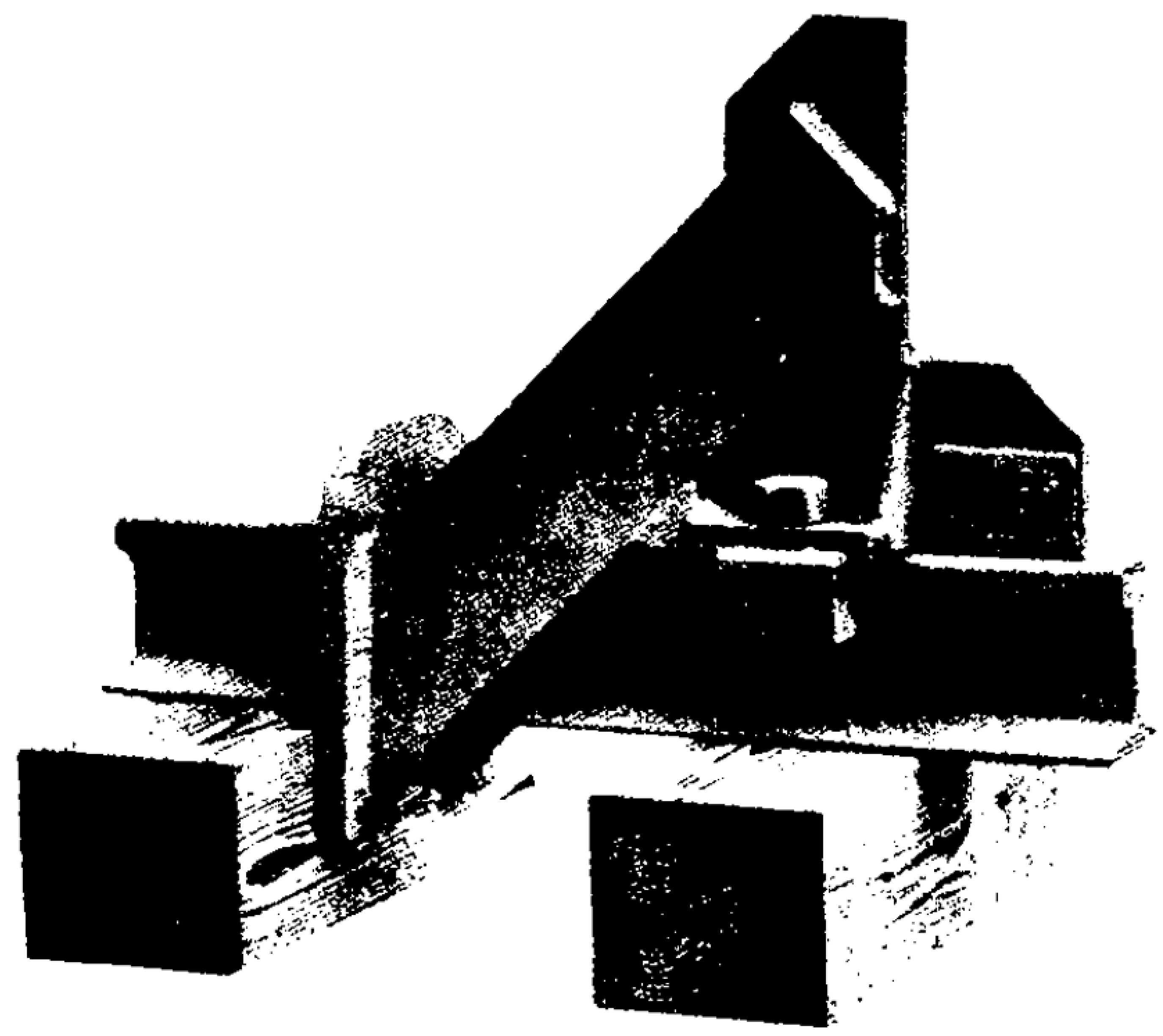


FIG. E - "HAYES" WHEEL STOP. **

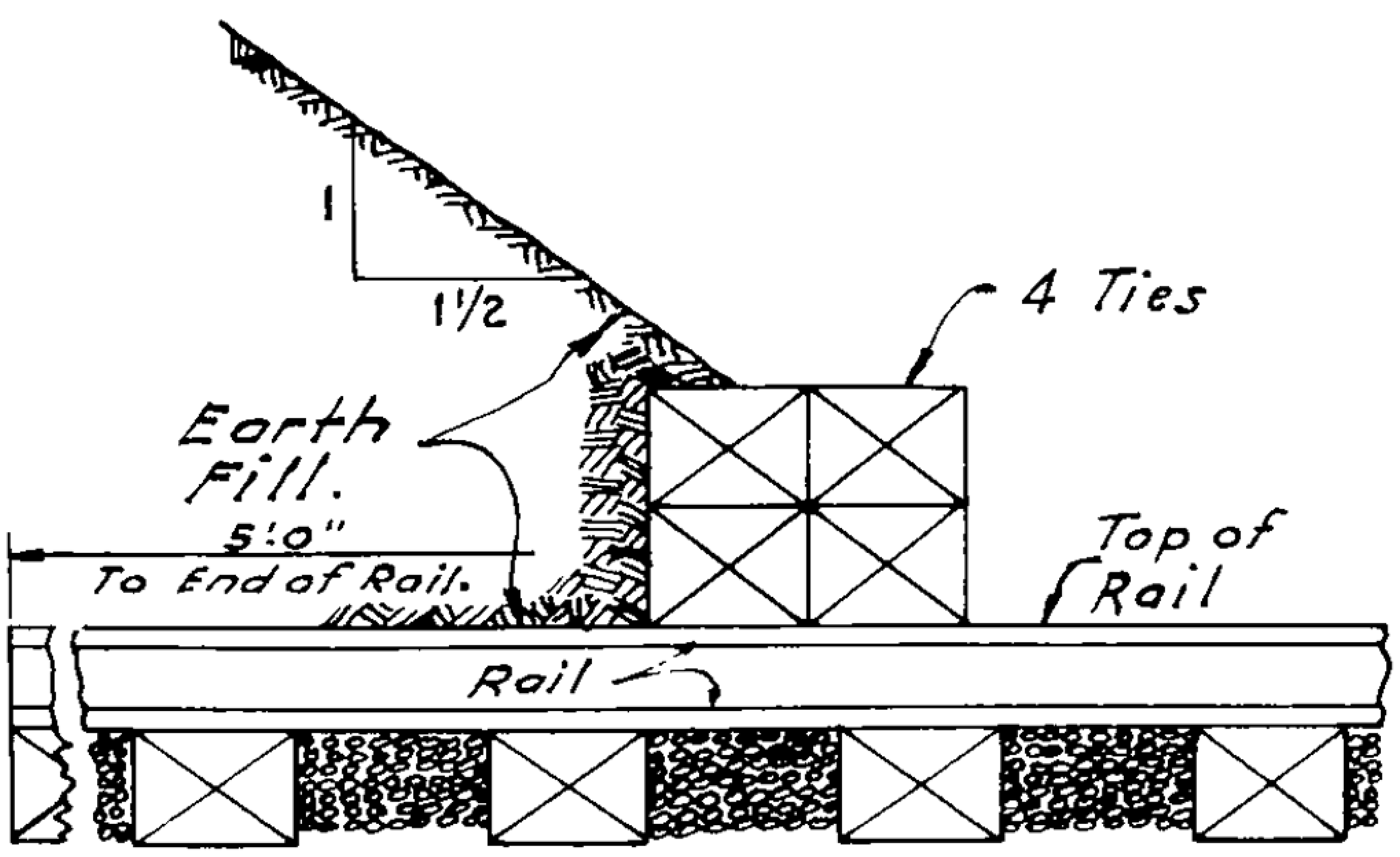


FIG. C - DETAIL OF TYPICAL CAR BUMPER.

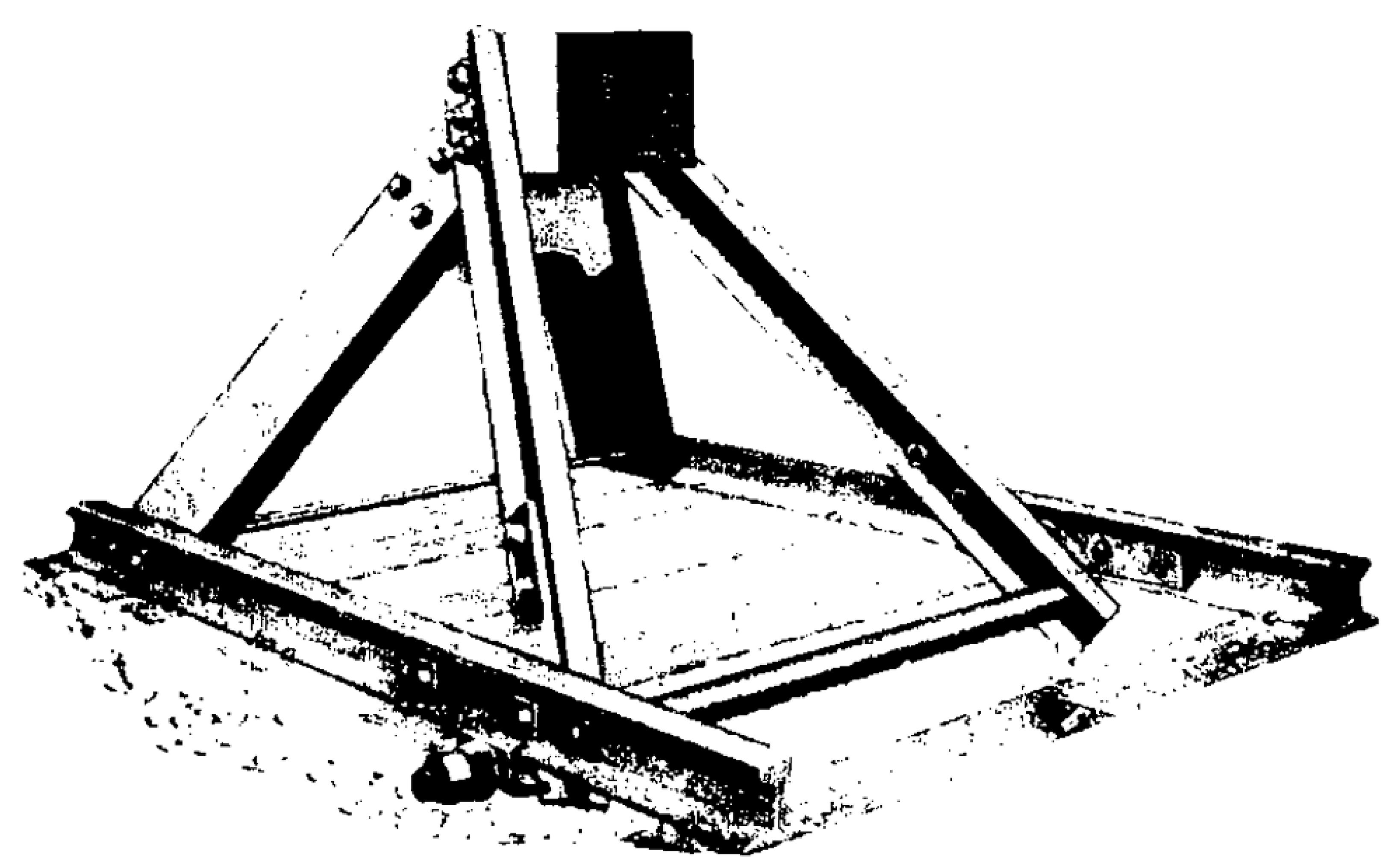


FIG. F - "DURABLE" BUMPING POST. ***

*Adapted from Amer. Civil Engineers, Handbook by Merriman & Wiggin.
**Adapted from Hayes Track Appliance Co., Richmond, Indiana.
***Adapted from, A.B. Letterman Co., Chicago, Ill.

AIRPORTS - GENERAL - 1

FACTORS IN PLANNING

SIZE OF COMMUNITY SERVED SMALL UP TO 25,000 MEDIUM - 25,000 TO 250,000. LARGE - OVER 250,000.	Large cities will require one or more Class IV or V airports (See Pg 4-14 for CAA classes, etc.) as terminals for regularly scheduled services and one or more Class I, II or III airports for non-scheduled services. (See below for service classification.) Medium size cities will be adequately served by one class III airport, capable of expansion to Class V and with additional Class I or II airports as may be required. Small communities will require one Class I or II airport. Communities that are trading centers for large areas may require higher class airports than indicated by population. Study retail sales for this factor. All airports should be planned for expansion. Separation of regularly scheduled from non-scheduled flying is desirable when volume of traffic will make this economical. Such separation should be foreseen and planned.
TYPE OF SERVICE COMMUNITY MAY REQUIRE.	A.- Regularly scheduled - passenger, express and slow cargo and airmail, aerial taxi service. B.- Non-scheduled - private flying, schools for air training, sales and service of airplanes and parts, aerial taxi, crop dusting, fire prevention and conservation, tourist and sport travel, aerial photography, industrial freight, helicopters, air patrols by C.A.A. and others, glider trains, private gliding. All these services should be studied to estimate present and future volume of traffic.
REGIONAL PLANS AND EXISTING AIRWAYS.	Consult State and C.A.A. for conflict with other airports and airways. Several small communities may be best served by one airport; consolidation may allow a larger airport with increased services. Proximity to existing important airways may increase traffic at airport; may require airport be designed for emergency landings of large planes.
PLANE MOVEMENTS PER HOUR (P.M.H.).	The peak number of plane movements anticipated, present and future, should be estimated to determine the maximum number of runways required for use at one time. Landings require 2 or 3 times the time needed for take-offs. Contact (visible) operation - one runway - 30 landings + 30 take-offs = 60 P.M.H. (Plane movements per hour). Contact (visible) operation - two runways - 50 landings + 50 take-offs = 100 P.M.H. Contact (visible) operation - more than two runways - plane movements on ground and in air must be completely analyzed for interference. Instrument operation - one runway - 12 landings + 18 take-offs = 30 P.M.H. (Anticipated 1946 - 1948; 1944 max. 8-15). Instrument operation - two runways - 20 landings + 30 take-offs = 50 P.M.H. (Anticipated 1946 - 1948). It is anticipated that technical advances will increase instrument operation rates to approximate contact operation rates.
DESIGN PROCEDURE.	1. Prepare or select a preliminary master plan based on above factors. See Pg. 4-21 to 4-25 for suggested master plans. Show all future requirements. 2. Select site - See Pg. 4-11. 3. Prepare master plan - See Pg. 4-12.

AIRPORTS - GENERAL-2

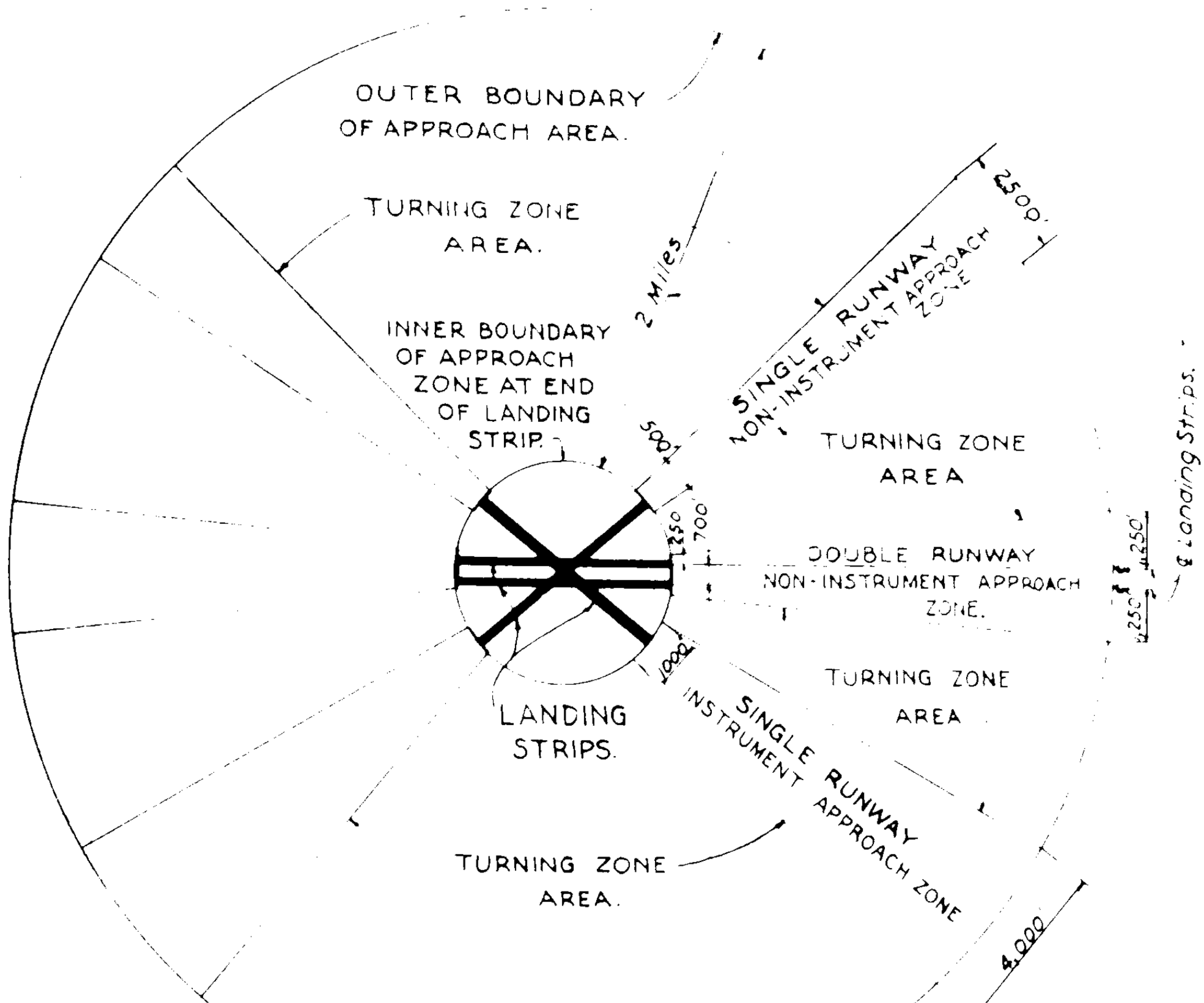
FACTORS IN SITE SELECTION	
PROXIMITY TO OTHER AIRPORTS.	6 miles between centers, minimum.
GROUND TRANSPORTATION.	Site should be served by adequate ground transportation facilities for passengers, freight, employees and visitors. Generally an express highway will be required for Class III, IV, V airports. Speed, allowable traffic volume, cost of existing or proposed facilities and distance from city are factors.
FUTURE EXPANSION.	Sufficient land available to buy or option to allow for economical development of master plan.
APPROACH ZONES.	See Pg. 4-13. Standards indicated must be complied with at any stage of master plan.
EXISTING OBSTRUCTIONS.	Practicability of removal of high building, stacks, power lines, etc., should be determined.
TOPOGRAPHY AND DRAINAGE.	Balanced costs of grading and drainage should be attained. Flat land requires excessive drainage. Hilly land requires excessive grading. Investigate floods at valley sites; destructive winds at elevated or exposed sites. Look for sites slightly above level of flat country or on long easy slopes in hilly country. Avoid sites with high ground water level for which the necessary subdrainage will be costly.
WIND.	Sites with prevailing wind from 1 or 2 directions may require runways in only 1 or 2 directions, thus reducing cost, taxiing time.
VISIBILITY.	Avoid kown areas of frequent fogs; often found along large water bodies and near industrial areas.
SOIL. See Pg. 3-03 for Classification.	A-1, A-2 or A-3 soils desirable; A-4 to A-7 soils require surface and subsurface drainage and substantial base and sub-base courses. Construction over A8 soil extremely costly.
CONSTRUCTION MATERIALS.	Short haul to deposits of A-1, A-2, A-3 soils or to stone quarries important.
UTILITIES.	Study cost of providing sewer, water, gas, electricity, gasoline, telephone, telegraph, etc.
EXISTING AIRWAYS.	Locate close to existing airways if other factors balance.
ZONING.	Zoning regulations should be able to be enacted to limit future building outside airport in accordance with Approach Standards. See Pg. 4-13.
NATIONAL DEFENSE.	Check with proper Army & Navy Authorities.

AIRPORTS - GENERAL-3

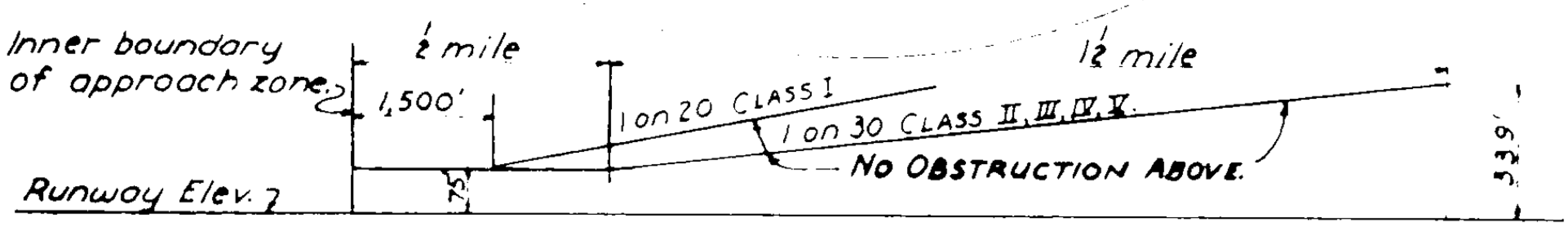
FACTORS IN PREPARING A MASTER PLAN.

PRELIMINARY SURVEYS.	Prepare property, location, topographic, existing airway, obstruction maps. Secure data for Wind Rose (See Pg. 4-19) and aerial photographs. Soil survey data should include identification of surface and subsoil, soil profiles, ground water table, location of available material deposits.
DIRECTION AND NUMBER OF LANDING STRIPS.	See Table page 4-14 for percentage of time that prevailing winds allow use of runways. Construct Wind Rose and compute coverage, see Pg. 4-19. The sample computation shows a triangular layout (3 Runways) will give 82% coverage which satisfies the requirements for a Class III airport. If factors for planning show the ultimate size airport to be Class III, a triangular layout is indicated. Runways and taxiway pattern to be planned for short and easy traffic flow. Long distance plane taxiing is at present uneconomical.
AIRPORT SIZE STANDARDS.	See Pg. 4-14 & 4-15 C.A.A. requirements for runway widths, lengths, grades, etc.
GROUND FACILITIES.	Ground facilities including administration building, hangars, loading and unloading platforms, and access roads to be planned for maximum efficient movement of passengers, freight and planes. Each landing plane should have direct route to loading or unloading area from end of runway. Administration building and parking to be designed for passengers, employees and visitors. Table A · Pg. 4-18 indicates minimum facilities.
LIGHTING	See Table B · Pg. 4-18 and Pg. 4-34, 35.
LIMITATION OF BITUMINOUS PAVEMENT.	For service aprons, parking aprons, hardstandings, turnarounds and all other pavement subject to high shearing stresses occurring when planes turn with locked wheels or subject to the action of oil and gasoline dripping and spilling, use concrete or surface treated gravel; bituminous pavement not indicated.
DESIGN OF PAVEMENT.	See pages 4-26 to 4-31 inclusive.
DRAINAGE DESIGN.	See Pg. 4-32 & 4-33.
COMPLETED PLANS TO INCLUDE.	Grading: Plans, profiles and sections with existing and finished grades for both present and ultimate development. Location of available construction material. Drainage: Plans, profiles, sections and details for all piping, ditches, subdrainage and structures for both present and ultimate development. Runways, Taxiways, Aprons, Parking Areas, Access Roads: Plans showing location and dimensions, intersection details, expansion joint details, Cross sections and profiles. All future paved areas to be indicated. Lighting: Size, type, location and details of lights, cables, transformer, underground ducts, control points and wiring. Utilities: Sewer, water, telephone, power complete for airport, including connections to outside source or disposal. Buildings: Location of all present and future buildings, including off-site proposed development, Plans in detail for present work. Zoning Plans: Sufficient to enact as local law. Stage Construction: Show time when construction of each item or part of master plan should be started and completed in order to satisfy estimated future air traffic requirements. Construction should not interfere with operation of airport.

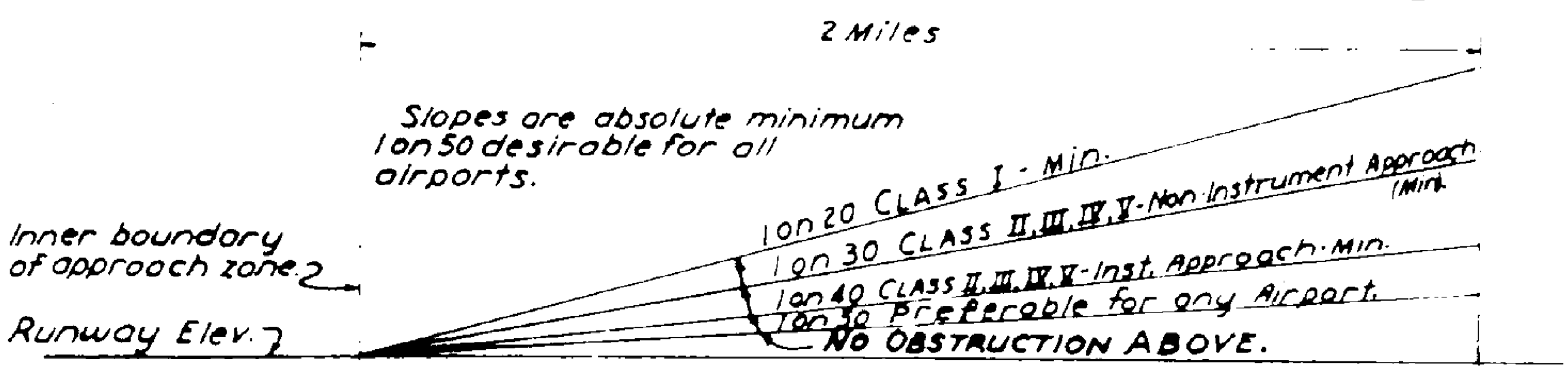
AIRPORTS – APPROACH STANDARDS*



PLAN



SECTION THROUGH TURNING ZONE AREA.



SECTION THROUGH APPROACH ZONE.

*Adapted from Dw'g - 152-C - Civil Aeronautics Administration.

AIRPORTS - C.A.A. STANDARDS - 1

	CLASS I AIRPORT	CLASS II AIRPORT	CLASS III AIRPORT	CLASS IV AIRPORT	CLASS V AIRPORT
Type of community.	Small communities not on present or proposed air carrier system. Includes communities up to a population of approximately 5,000.	Larger communities located on present or proposed feeder line airways and having considerable aeronautical activity. General population range 5,000 to 25,000.	Important cities on feeder line airway systems and many intermediate points on the main line airways. General population range 25,000 to several hundred thousand.	Cities in this group represent the major industrial centers of the nation & important junction points or terminals on the airways system.	Same as Class IV.
Type of plane which airport may safely accommodate. See Pg. 4-17 for Weights and wing loading times power loading factors.	Small private owner type planes up to gross weight of 4,000 lb., or those whose wing loading times power loading does not exceed 190.	Large private planes and some small transport planes in gross weight range between 4,000 and 15,000 lb., or having a wing loading x power loading of 190 to 230.	Present day transport planes between 10,000 lb. and 50,000 lb. gross weight, or having a wing loading x power loading of 230 and over.	Largest planes in use and those planned for immediate future with a gross weight of 74,000 lb. and over, or a wing loading x power loading of 230 and over.	Same as Class IV.
length of landing strips*	1,800 to 2,700 ft.	2,700 to 3,700 ft.	3,700 to 4,700 ft.	4,700 to 5,700 ft.	over 5,700 ft.
Width of usable land strips	300 ft.	500 ft.	500 ft.	500 ft.	500 ft.
length of runways.	None	2,500 to 3,500 ft.	3,500 to 4,500 ft.	4,500 to 5,500 ft.	over 5,500 ft.
Width of runways.	None	150 ft. night operation. 100 ft. day operation only.	200 ft. for instrument landing. 150 ft. night operation.	Same as Class III.	Same as Class III.
Required coverage or percentage of time** that prevailing winds including calms*** permit use of landing strips and runways. See Pg. 4-19.	70 per cent.	75 per cent.	80 per cent.	90 per cent.	90 per cent.
Min. distance between center lines of parallel runways.		700 ft.	700 ft.	700 ft.	700 ft.
Min. distance between center line of runway and airport buildings. Instrument landing runway.		750 ft.	750 ft.	750 ft.	750 ft.
Minim. distance between center line of runway and aprons and loading platforms. Instrument landing runway.		500 ft.	500 ft.	500 ft.	500 ft.

For notes see Pg. 4-15.

AIRPORTS - C.A.A. STANDARDS - 2

	CLASS I AIRPORT	CLASS II AIRPORT	CLASS III AIRPORT	CLASS IV AIRPORT	CLASS V AIRPORT
Distance between center line of runway and airport buildings. All other runways.	Desirable : Minimum :	500 ft. 350 ft.	500 ft. 350 ft.	500 ft. 350 ft.	500 ft. 350 ft.
Minim. distance between center line of runway and aprons, loading platforms & parking areas. All other runways.		250 ft.	250 ft.	250 ft.	250 ft.
Landing strip and runway grades - transverse.	2% Maximum	2% Maximum.	1 1/2% Maximum.	1 1/2% Maximum.	1 1/2% Maximum.
Landing strip and runway grades - uniform longitudinal.	2% Maximum.	1 1/2% Maximum.	1 1/2% Maximum.	1% Maximum.	1% Maximum.
Grade breaks - longitudinal **** Maxim. algebraic difference.	3%	2 1/2%	2%	2%	2%
Gross plane weights for runway, taxiway & apron paving based on present day aircraft; to be considered distributed equally between two main wheels or sets of wheels.	No paving recommended.	30,000 lb.	74,000 lb.	120,000 lb.	120,000 lb.
Probable future (10 yrs) maximum static gross plane weight to be considered in the design of runway, taxiway & apron paving and drainage structures.	20,000 lb.	60,000 lb.	150,000 lb.	300,000 lb.	300,000 lb.
Recommended gross weight to use for design.	20,000 lb.	60,000 lb.	150,000 lb.	300,000 lb.	300,000 lb.
Probable range of static airplane tire pressure.	10 to 25 psi.	15 to 50 psi.	30 to 75 psi.	50 to 85 psi.	50 to 85 psi.

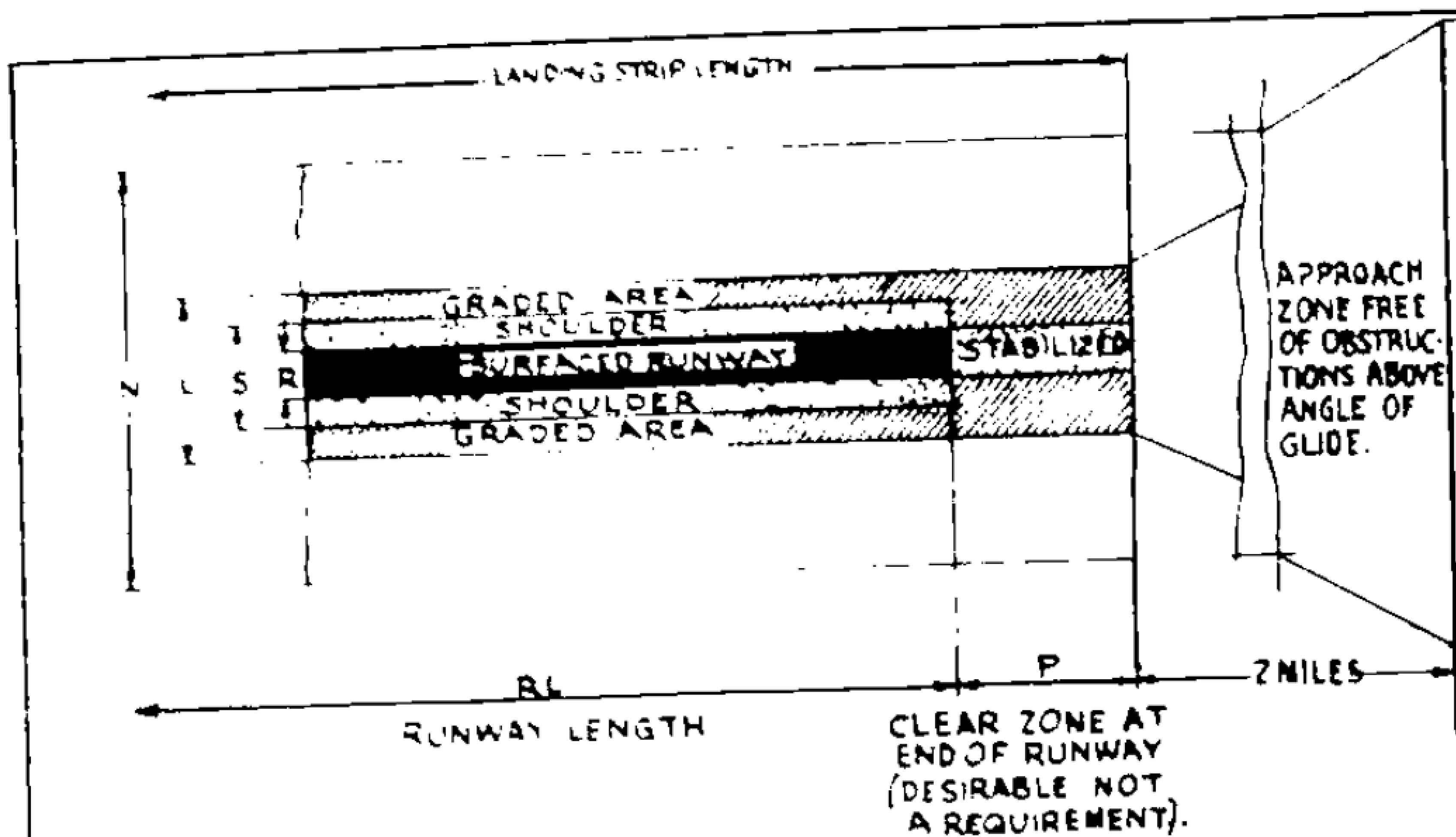
*All of the above landing strip and runway lengths are based on sea level conditions; for altitudes above sea level increase runway length 25' for each 100' increase in elevation. One surfaced runway is recommended for each landing strip for airports in Classes II, III, IV & V.

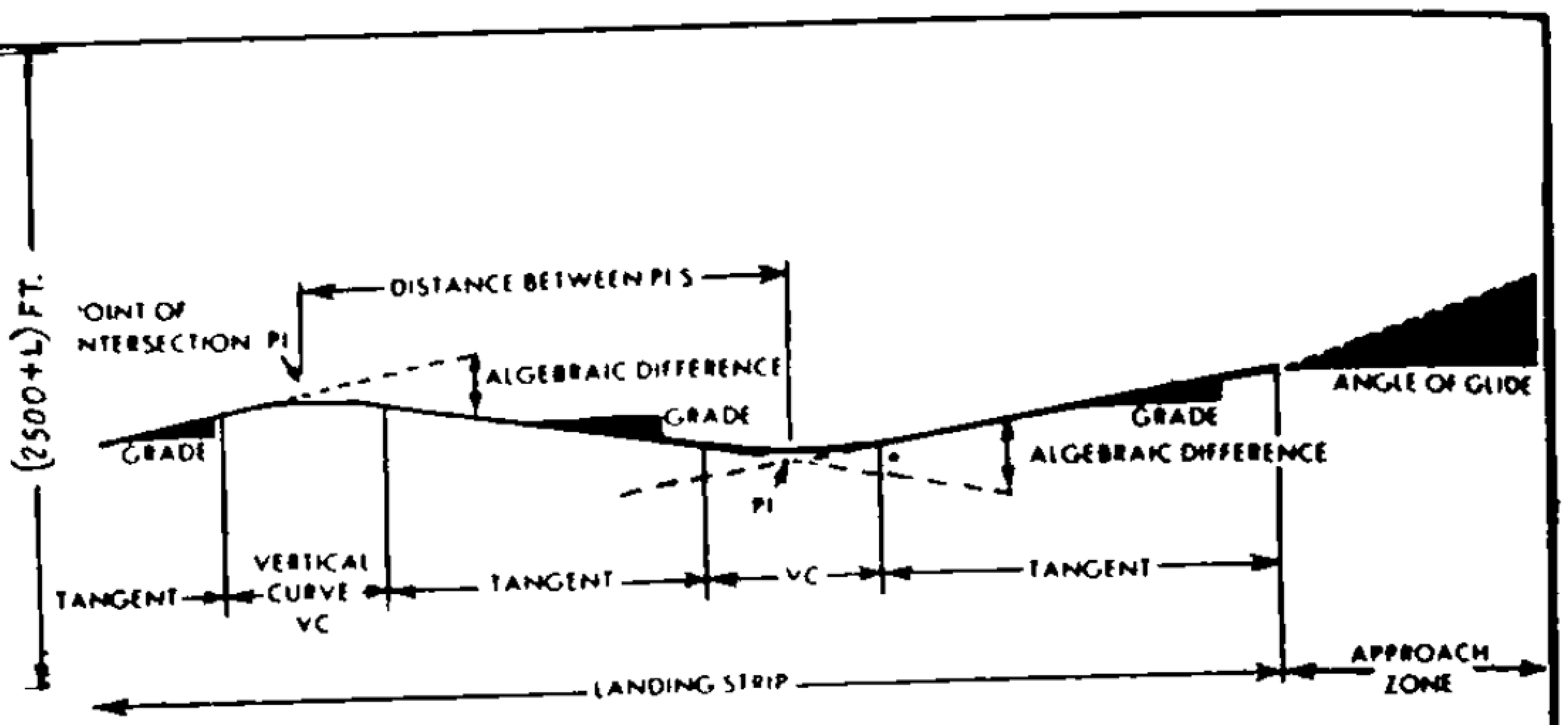
**Landing strips and runways should be sufficient in number to permit take-offs and landings to be made within 22 1/2 deg. of the true wind direction for the percentage shown above of winds 4 mph and over based on at least a 10 year Weather Bureau wind record where possible.

***Winds 3 mph and less.

****Intersecting grades should be joined by a vertical curve, if the algebraic difference in grades is 0.40% or more. The vertical curve should be at least 300' in length for each 1% change in grade. The tangent interval between the point of tangency of the curve and the point of curvature of the succeeding curve should be not less than 1000'. If economically practical grade breaks should be so controlled that the sight line will be unobstructed from any pt. 10' above the surface of the runway to any other pt. 10' above the runway.

AIRPORTS - ARMY STANDARDS*





NOTE: RUNWAY EXTENSION IN CLEAR ZONE STABILIZED TO CARRY OCCASIONAL PLANES

PLAN

LONGITUDINAL SECTION**

CRITERIA FOR LONGITUDINAL GRADE ALONG CENTER LINE OF LANDING STRIP.

1. Distance between P.I.s not less than 1000 ft.
2. Vertical curves: Minimum length 666 ft. per each 1% algebraic difference.
3. Longitudinal grade: Not greater than 1% for heavy bombers and not greater than 1½% for lighter aircraft.
4. Angle of glide: Obstruction free slope 1 on 40 is desired. Military necessity may require steeper slope but in no case shall it be steeper than 1 on 20.
5. Visibility: There must be unobstructed view from any point 10 ft. above runway to any other point 10 ft. above runway for length of runway, but not over 7,000 ft.

FIG. A-CRITERIA FOR LANDING STRIPS & RELATED ELEMENTS. (SEE TABLE BELOW)

TABLE B- RECOMMENDED DIMENSIONS & CLEARANCES FOR AIRDROMES.

Type of aircraft	Length (feet): Runway length at sea level* RL Minimum	Length (feet): Clear zone at each end of runway P Desired	Type of location	Width (feet): Runway R Minimum	Width (feet): Runway and shoulders S Minimum	Width (feet): Landing strip L Minimum	Width (feet): Safety clearance zone N Minimum	Taxiway See Note below. T Minimum.
Fighters and light bombers, such as P 38, P 39, P 40, P 47, P 51, A 20, A-24, A-36. Cargo, such as C-47, C-53, C-60.	4,000	500	Wooded or jungle	100-150	200-300	300-400	1,000	30
			Open or desert	150	300	300-500	1,000	
Medium and heavy bombers, such as B 25, B-26, B 17, B 24. Cargo, such as C-45, C-46, C-54.	5,000	1,000	Wooded or jungle	150	250-300	300-400	1,000	50
			Open or desert	150	300	300-500	1,000	
Superbombers, such as B 29. Heavy Cargo	7,000	1,000	Wooded or jungle	200	300-400	400	1,000	75
			Open or desert	200	300-500	500	1,000	

NOTES:

Length of runway is increased 10 percent of sea-level length for each 1,000 ft. of elevation of site above sea level. In regions of prevailing high temperature or of prevailing low atmospheric pressure an additional 10 percent is desirable. Recommended minimum lengths of landing strips at advanced landing fields without runways are same as minimum runway lengths.

TAXIWAYS:

Increase widths 10 feet on sharp curves.

Cleared zone on each side of taxiway extends out a distance, measured from edge of stabilized, surfaced, or paved section equal to one-half the wing span of largest aircraft using airdrome.

Longitudinal grade along center line of taxiway preferably should not exceed 2% and in no case should exceed 3%.

*Adapted from Aviation Engineers' Manual. **See page 4-20 for cross-section.

AIRPORTS – AIRPLANES

(REVISED: OCTOBER 25, 1946)

TABLE A – AIRPLANES THAT CLASS I AIRPORTS CAN ACCOMMODATE

COMPANY	MODEL	INDEX №	GROSS WT.
AERONCA	ALL MODELS		
ARROW	F	179	1650
BEECH	D17A	174	4250
BEECH	E17B	136	3390
BEECH	F17D	132	3590
BEECH	G43 (GB-2)	136	4250
BELLANCA	14-13 (CRUISAIR SR.)	182	2100
BELLANCA	14-12-F3 (CRUISAIR)	185	1900
BOEING	N2S-4 (P.T.-17)	113	2700
CESSNA	120	155	1450
CESSNA	140	155	1450
COMMONWEALTH	8135	186	1900
CULVER	LCA	189	1305
CURTISS-WRIGHT	A-19-R	110	2837
CURTISS-WRIGHT	CW-22 SPORT	140	3200
ENG.& RESEARCH	A-718-1	157	1300
FAIRCHILD	P.T.-19A	172	2459
FAIRCHILD	KR-21A	138	1550
FUNK	B75L	144	1350
FLEET	1 AND 2	116	1580
HARLOW	PIC-1	189	2251
INTERSTATE	L-6	139	1650
KINNER	SPORTSTER K	155	1875
LUSCOMBE	8-A	159	1200
LUSCOMBE	PHANTOM 1	182	1950
MONOCOUPE	110	179	1611

COMPANY	MODEL	INDEX №	GROSS WT.
NEW STANDARD	D-25	150	3400
PIPER	CRUISER J5A	157	1450
PIPER	STD. TRAINER & L-4B	136	1160
PIPER	COUPE JR-E	143	1400
PIPER	P.T.	188	2000
PIPER	SPORT	136	1100
REARWIN	812 CLAUDSTER 5	186	1900
REARWIN	SPEEDSTER	162	1700
REARWIN	SPORTSTER -9000	142	1460
RYAN	S-T-4 SPECIAL	138	1600
RYAN	S.C.	158	2150
RYAN	P.T. 22 (NR-1) ST-3	160	1860
RYAN	ST-35	190	2021
RYAN	PT-25 ST-4	108	1800
STEARMAN	HAMMOND	161	2250
ST. LOUIS	PT-LM-4	142	2012
ST. LOUIS	PT-23-SL	143	2583
SPARTAN	NP-1	137	2955
SWALLOW	C	163	1980
TAYLORCRAFT	L2B	122	1250
TAYLORCRAFT	TRAINER	131	1200
TAYLORCRAFT	BT	121	1150
WACO	VKS7F	180	3250
WACO	UPF-7	131	2650

TABLE B – AIRPLANES THAT CAN BE ACCOMMODATED BY CLASS II AIRPORTS

COMPANY	MODEL	INDEX №	GROSS WT.
BEECH	AT-10	204	6000
BEECH	D18C	221	9000
BEECH	35 C	198	2550
BELLANCA	14-13-A (CRUISAIR SR.)	191	2150
BELLANCA	31-55 (SKYROCKET)	192	5600
BELLANCA	14-9 (JUNIOR)	199	1700
BOEING	247-D	202	14000
BOEING	417	366	18750
CESSNA	AIRMASTER C-145	229	2450
CESSNA	AT-8	195	5100
CESSNA	AT-17D	195	5100
CESSNA	T-50	195	5100
FAIRCHILD	24W-41A	227	2550
FAIRCHILD	45A	201	4000
FAIRCHILD	C-61A	221	2801
HARLOW	PC-5A	252	2600

COMPANY	MODEL	INDEX №	GROSS WT.
HOWARD	DGA-15P	226	4350
LANGLEY	2-4-90	210	2550
MONOCOUPE	90-A	218	1610
MORROW	10L	219	2400
NORTH AMERICAN	AT-6 (SNJ-4)	197	4158
NORTHROP	N-3PB	201	10600
ONG	M-32W	220	2300
PHILLIPS	1-B	206	2180
SPARTAN	EXECUTIVE 7W	194	4400
SPARTAN	C-71	194	4400
STINSON	RELIANT SR 10F	209	4650
STINSON	VOYAGER	201	1680
STINSON	105	215	1580
WACO	EGC	206	3800
WACO	ZVN	198	3650

TABLE C – AIRPLANES THAT CAN BE ACCOMMODATED BY CLASS III TO V AIRPORTS

COMPANY	MODEL	INDEX №	GROSS WT.
BARKLEY GROW	T8P1	270	8750
BEECH	AT-11 (SNB-1)	243	8727
BELL	P-39 (AIRACOBRA)	234	7573
BELLANCA	66-70 (AIRCRUISER)	260	11400
BENNETT	EXECUTIVE BCT-1	262	6395
BOEING	307	378	45000
BOEING	C-97		120000
BOEING	STRATOCRUISER	749	135000
CESSNA	C78 (BOBCAT)	244	5700
CONSOL-VULTEE	240	397	39000
CURTISS-WRIGHT	CW-20	459	50000
CURTISS-WRIGHT	P-40F	282	9080
CURTISS	C-46	372	45000
CURTISS	AT-9	255	5764
DOUGLAS	C-47, -A, -B	305	26900
DOUGLAS	C-74	698	145000
DOUGLAS	DC-2	258	18560
DOUGLAS	DC-3, -A, -B, -C, -D	268	25200

COMPANY	MODEL	INDEX №	GROSS WT.
DOUGLAS	DC-4	631	73000
DOUGLAS	DC-6	648	93200
HARLOW	PJC2	252	2600
HOWARD	DGA-15W	282	4350
LOCKHEED	ELECTRA 10E	268	10500
LOCKHEED	C-69 (CONSTELLATION)		85000
LOCKHEED	A-29 (PBO)	310	18500
LOCKHEED	AT-18	310	18500
LOCKHEED	C-60 (18-10 & 14)	295	18500
LOCKHEED	14 G-3B	328	17500
LOCKHEED	14H	280	15500
LUSCOMBE	90	236	1275
MONOCOUPE	110 SPECIAL	265	1630
REPUBLIC	RAINBOW		113250
STINSON	A	267	10200

Index № = Wing Loading in lb. per sq. ft. × Power Loading in lb. per HP.

$$\text{Wing Loading} = \frac{\text{permissible gross load}}{\text{wing area}}\;;\quad \text{Power loading} = \frac{\text{gross weight}}{\text{available HP}}$$

Adapted from Airport Design by C.A.A.

AIRPORTS - FACILITIES, LIGHTING & TAXIWAYS

TABLE A - MINIMUM FACILITIES RECOMMENDED BY C.A.A.

FACILITIES \ CLASS	I	II	III, IV, V
Drainage	Include	Include	Include
Fencing	✓	✓	✓
Marking	✓	✓	✓
Wind Direction Indicator	✓	✓	✓
Hangar	✓	✓	✓
Shop		✓	✓
Fueling		✓	✓
Weather Information		✓	✓
Office Space		✓	✓
Parking		✓	✓
Weather Bureau			✓
Two Way Radio			✓
Visual Traffic Control			✓
Administration Bldg.			✓
Taxiway & Aprons			✓
Instrument Approach System - when required.			✓

TABLE B - MINIMUM LIGHTING RECOMMENED BY C.A.A.

LIGHTING \ CLASS	I	II	III	IV & V
BASIC LIGHTING: Airport Beacon,[1] Boundary Lights,[2] Range Lights, Obstruction Lights, Illuminated Wind Cone.	Optional	Include	Include	Include
Contact Lights (Including Range Lights)		✓	✓	✓
Illuminated Wind Tee or Tetrahedron			✓	✓
Landing Area Floodlighting[3]			✓	✓
Apron Floodlighting			✓	✓
Ceiling Projector			✓	✓
Taxi Lights				✓
Approach Lights[4]				✓
Approximate KW needed	10-15	15-20	20-40	40-80+

1. The installations of auxiliary beacons, such as identification code beacons, will depend upon individual requirements in each case.
2. Use boundary lights in lieu of contact lights at all-way type field having no all-night operator to select landing directions.
3. Landing area floodlights are considered necessary in northern climates where blowing snow conditions are encountered.
4. Approach lights should be installed for every instrument runway. See pg. 4-34 & 35 for location of lighting, etc.

TABLE C - TAXIWAY STANDARDS RECOMMENDED BY C.A.A.

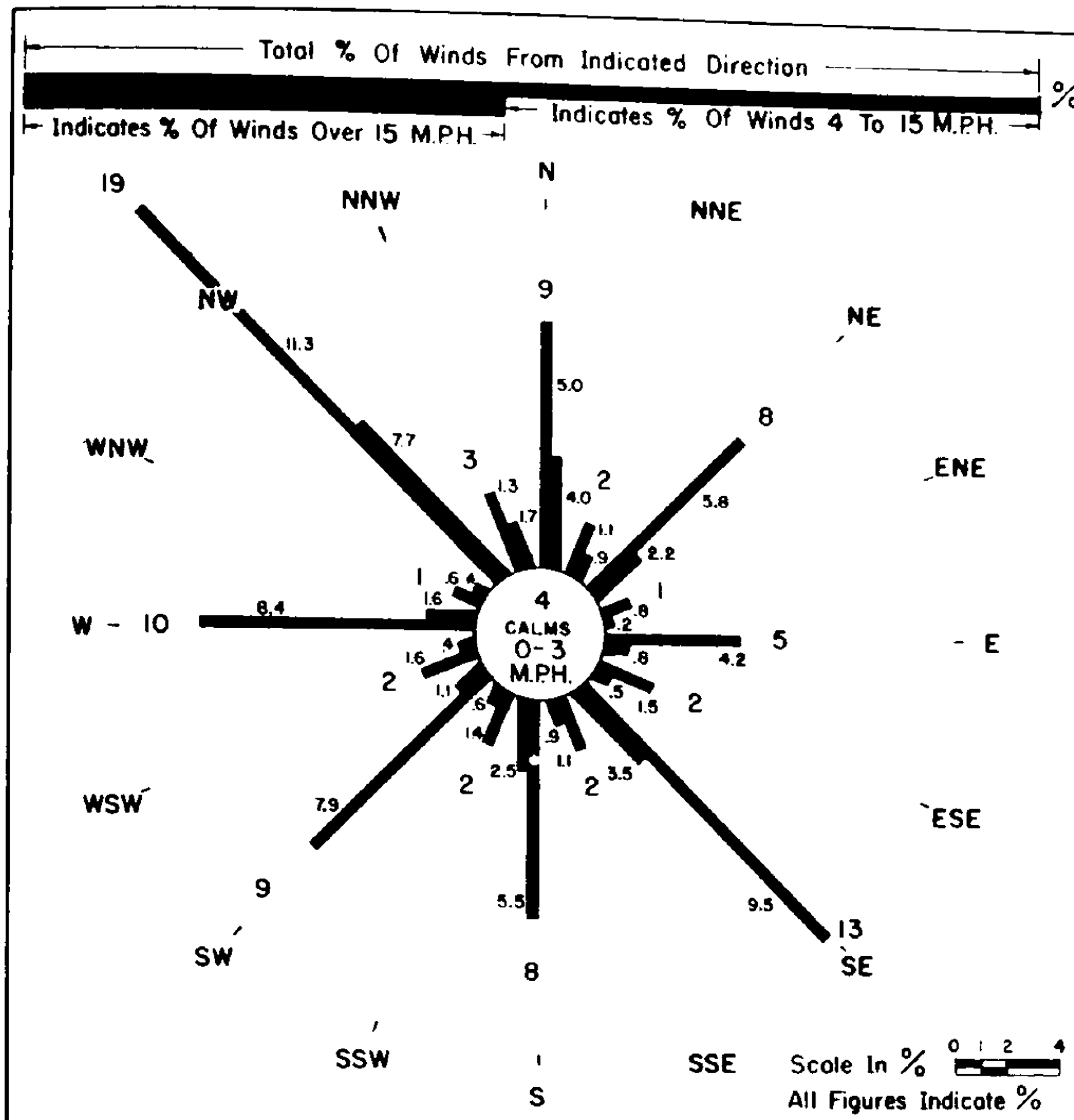
STANDARDS \ CLASS	II	III	IV	V
Minimum Width of Taxiways.	50'	50'	50'	50'
Minimum distance between runway center line and parallel taxiway center line.	275'	275	275'	275'
Minimum distance from boundary fence, obstructions, etc., to taxiway center line.	100'	150'	150'	200'
Maximum longitudinal grade.	3%	$2\frac{1}{2}$%	$2\frac{1}{2}$%	$2\frac{1}{2}$%
Maximum transverse grade.	$1\frac{1}{2}$%	$1\frac{1}{2}$%	$1\frac{1}{2}$%	$1\frac{1}{2}$%
Minimum Angle of taxiway intersection with runway ends.	60°	60°	60°	60°

Runway grades should not be altered to meet taxiway intersections or connections.

At large airports where traffic is heavy it may be advisable to construct a warming up apron and bypass on taxiways connecting to the ends of runways.

Taxiways should not connect to the ends of runways at an angle of less than 90° to incoming traffic.

AIRPORTS — WIND ROSE



PLOTTING OF WIND ROSE.

The data required are the average hourly velocity and direction of the wind for a period of years, 10 years if possible. Secure this data from local observation, U.S. Weather Bureau or C.A.A. Convert hourly data into percentages of the total and plot as shown in sample Wind Rose. To compute Wind Coverage see Fig. B below. Coverage refers to % of time that airport runways may be used for landings as determined by wind velocity and direction.

FIG. A — SAMPLE WIND ROSE*

SAMPLE COMPUTATION FOR RUNWAY COVERAGE OF WINDS*										
Wind Direction	% of Winds - in M.P.H.			Reducing to 8 Points			4 Runway Directions	Runway Coverage 22.5° Each Side		
	4-15	15 Up	Total	4-15	15 Up	Total		4-15	15 Up	Total
N	5.0	4.0	9.0	6.2	5.3	11.5	N-S	12.95	8.55	21.5
NNE	1.1	0.9	2.0							
NE	5.8	2.2	8.0	6.75	2.75	9.5	NE-SW	16.15	4.35	20.5
ENE	0.8	0.2	1.0							
E	4.2	0.8	5.0	5.35	1.15	6.5	E-W	14.85	3.15	18.0
ESE	1.5	0.5	2.0							
SE	9.5	3.5	13.0	10.8	4.2	15.0	NW-SE	23.05	12.95	36.0
SSE	1.1	0.9	2.0							
S	5.5	2.5	8.0	6.75	3.25	10.0				
SSW	1.4	0.6	2.0							
SW	7.9	1.1	9.0	9.4	1.6	11.0				
WSW	1.6	0.4	2.0							
W	8.4	1.6	10.0	9.5	2.0	11.5				
WNW	0.6	0.4	1.0							
NW	11.3	7.7	19.0	12.25	8.75	21.0				
NNW	1.3	1.7	3.0							
CALMS	-	-	4.0	-	-	4.0		-	-	4.0
TOTALS	67.0	29.0	100.0	67.0	29.0	100.0		67.0	29.0	100.0
COL. NO.	1	2	3	4	5	6	7	8	9	10

EXPLANATION OF SAMPLE COMPUTATION.

Col. 1 & 2 are taken from Wind Rose.
Col. 3 is sum of Col. 1 and 2.
Col. 4, 5 & 6 values are equal to Col. 1, 2 or 3 values + 1/2 sum of values above or below in Col. 1, 2 or 3. The 8 points selected are at 45° from the max. value in Col. 3.

__Example for SE:__
__Given__: Col. 1, 2, 3. __Required__: Col. 4, 5 & 6.
__Solution__: Col. 4 value = 9.5 + 1/2 (1.5 + 1.1) = 10.8 ; Col. 5 value = 3.5 + 1/2 (.5 + .9) = 4.2 ; Col. 6 value = 13 + 1/2 (2 + 2) = 15.
Col. 6 value also equals Col. 4 value + Col. 5 value = 10.8 + 4.2 = 15.0.
Col. 8, 9 & 10 are reduction to 4 directions by adding values in Col. 4, 5 & 6.

__EXAMPLE FOR NW-SE__: __Given__: Col. 1 through 6. __Required__: Col. 8, 9 and 10. __Solution__: Col. 8 value = 10.8 (from Col. 4 opp. SE) + 12.25 (from Col. 4 opp. NW) = 23.05; Col. 9 value = 4.2 + 8.75 = 12.95; Col. 10 value = 15 + 21 = 36; Col. 10 value also equals Col. 8 value + Col. 9 value = 23.05 + 12.95 = 36.00.

__CHECK OF COMPUTATIONS__ — Col. 3, 6 and 10 must total 100 %.

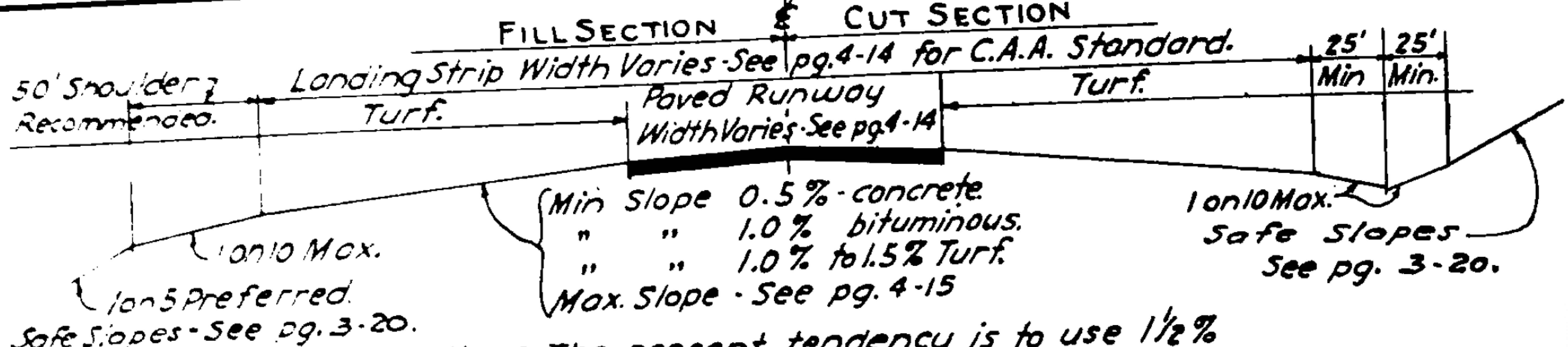
COVERAGE PROVIDED BY 1 TO 4 RUNWAYS.

1 Runway - 36 % (Max. value in Col. 10) + 4 % (for Calms) = 40 % = NW-SE Runway.
2 Runways - 40 % (above) + 21.5 % (next largest value in Col. 10) = 61.5 % = NW-SE, N-S.
3 Runways - 61.5 (above) + 20.5 % (next largest value in Col. 10) = 82 % = NW-SE, N-S, NE-SW.
4 Runways - oriented at 45° will always give 100 % coverage.

FIG. B — USE OF WIND ROSE.

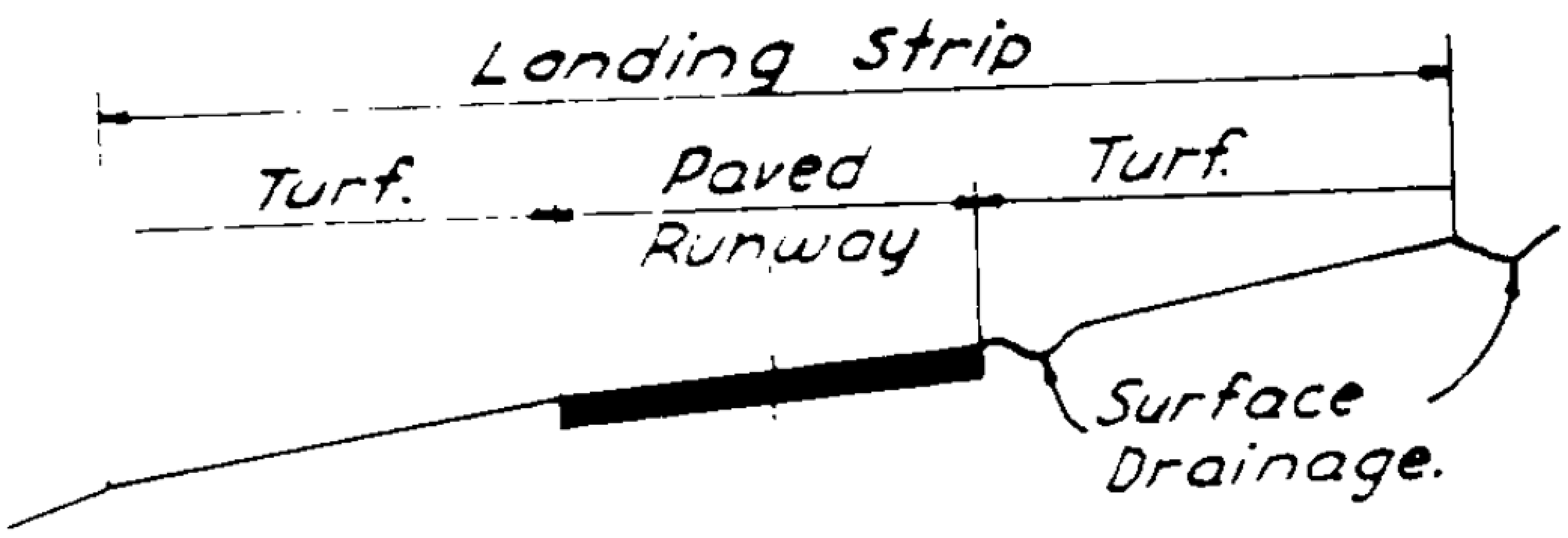
* *Adapted from C.A.A.*

AIRPORTS – CROSS SECTIONS



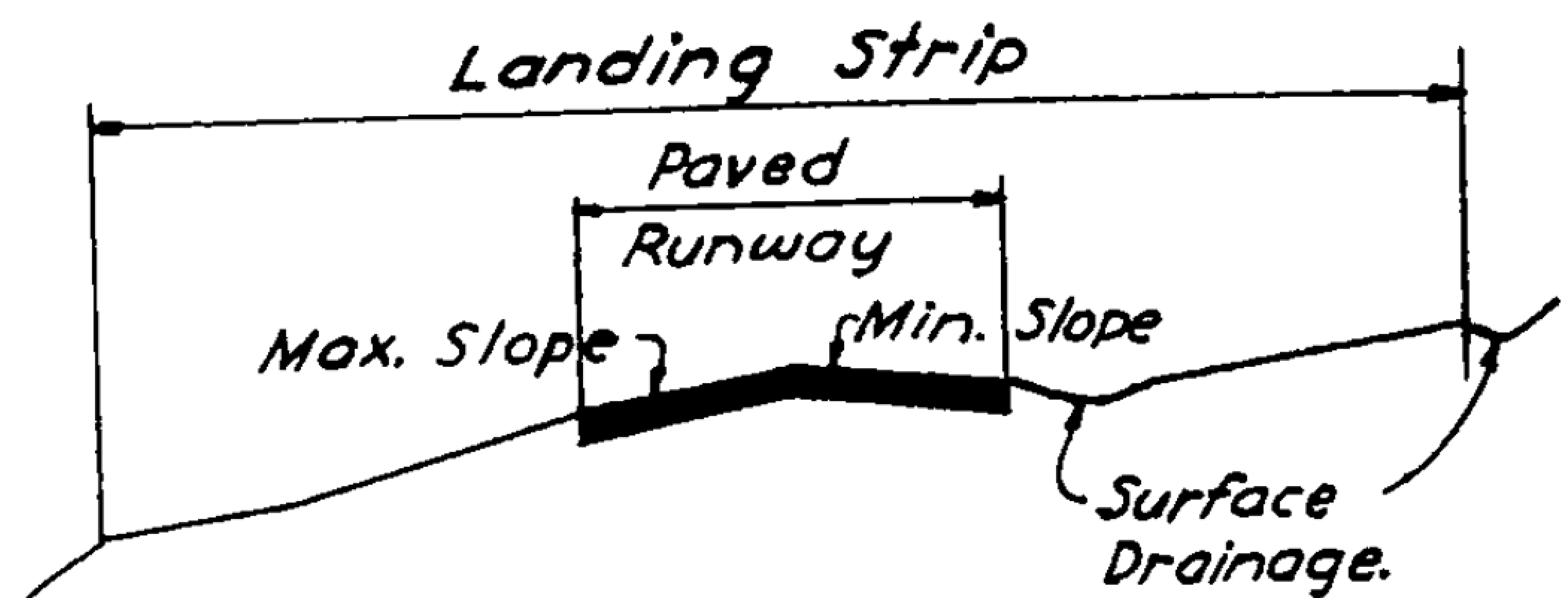
NOTE: The present tendency is to use 1½% as a minimum slope for runways and shoulders.

FIG. A - CROWNED RUNWAY.



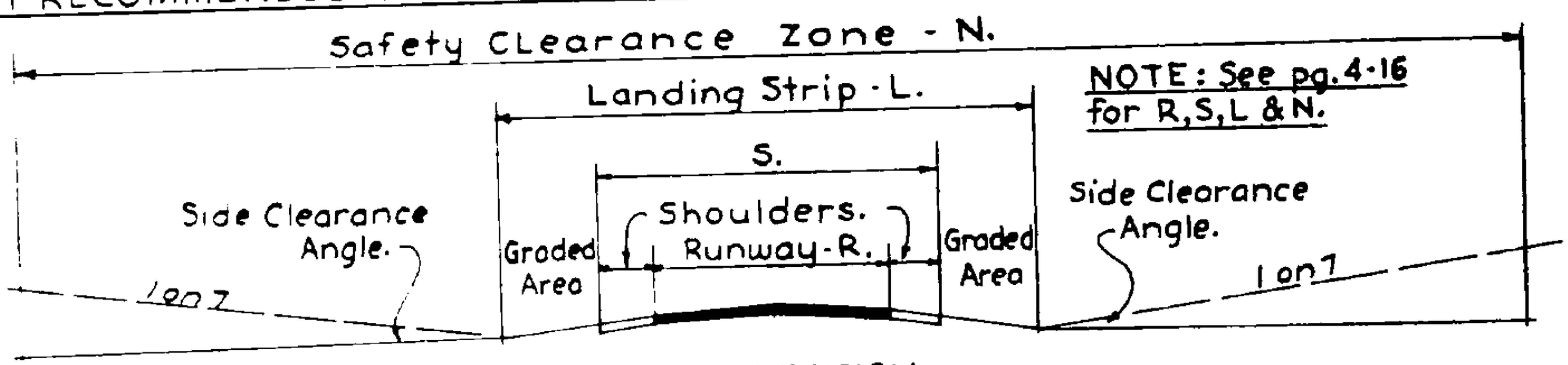
For Maximum and Minimum Slopes - See Fig. A.

FIG. B - RUNWAY ON SLOPE
NOT RECOMMENDED - FIG. C PREFERRED.



For Maximum and Minimum Slopes - See Fig. A.

FIG. C - CROWNED RUNWAY ON SLOPE.



CROSS SECTION.

NOTES:
1. Shoulders: Stabilized to carry additional planes.
2. Graded Area: Graded, compacted and drained to carry planes except during wet weather. No obstruction of any kind permitted.
3. Safety Clearance Zone:
   No grading except as specifically required by airdrome commander. Normally tree tops or other objects should be removed if they project above a 1 on 7 slope from edge of landing strip. Control Tower permitted.
4. No ponding of surface water at edge of runway pavement.
5. Surface drainage of shoulder should be away from runway pavement.
6. Slope of shoulder same as runway.
7. Slope of graded area not less than slope of shoulder and may be ½% more.

CRITERIA FOR CROSS SLOPES.

SURFACE	SLOPE	
1. Compacted Earth and Bituminous surfaces other than asphaltic concrete.	1½% Min. - 2% Max.	For regions of light precipitation, transverse slope may be 1% Minimum.
2. Asphaltic Concrete.	1½%	
3. Portland cement concrete.	1% Min. - 1½% Max.	

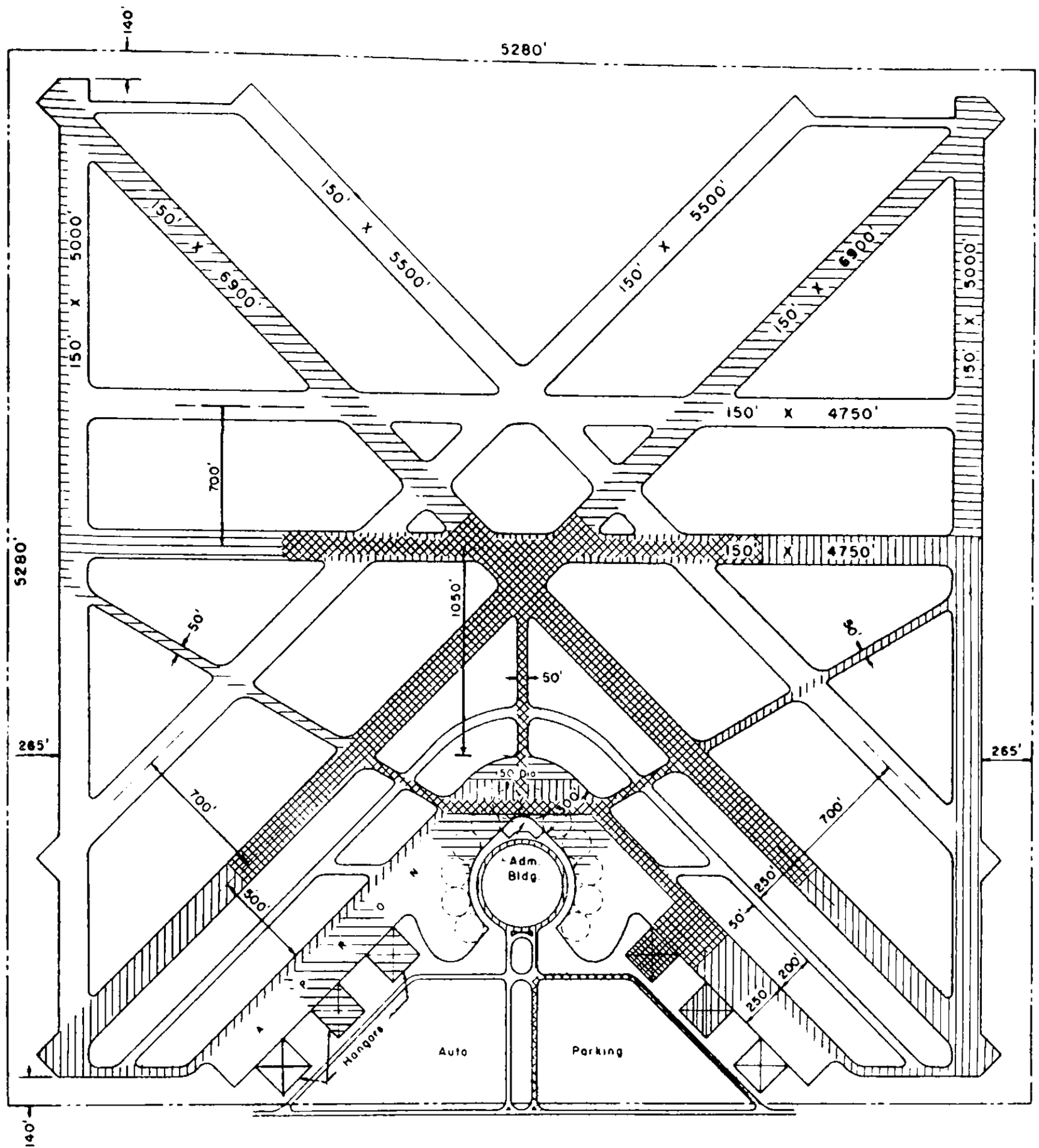
Subgrades are cross sloped, preferably same as finished surface, but not less than 1%

FIG. D - STANDARD ARMY CROSS SECTION AND CRITERIA.*

See pg. 4-16 for additional Army Standards.

*Adapted from Aviation Engineers' Manual.

AIRPORTS — MASTER PLANS-1



LEGEND

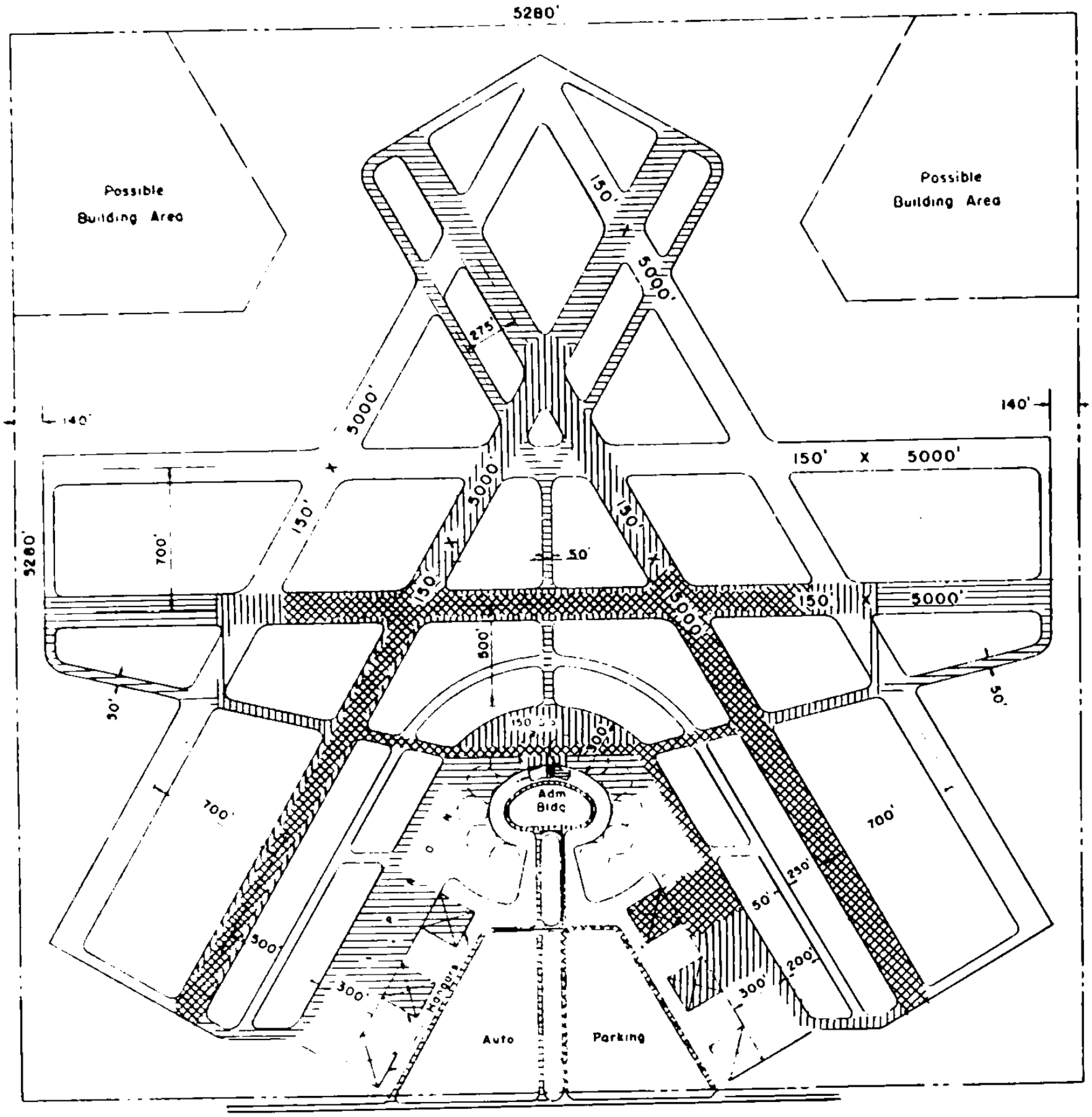
- Class I Development.
- Class II "
- Class IV "
- Ultimate "

Increase 4750' and 5000' runways to 5500' for Class V Airport.

CLASS IV AIRPORT - RECTANGULAR RUNWAY ALIGNMENT.*
AREA REQUIRED = 1 SQ. MILE.
STAGE DEVELOPMENT SHOWN.

*Adapted from C. A. A.

AIRPORTS — MASTER PLANS-2



LEGEND

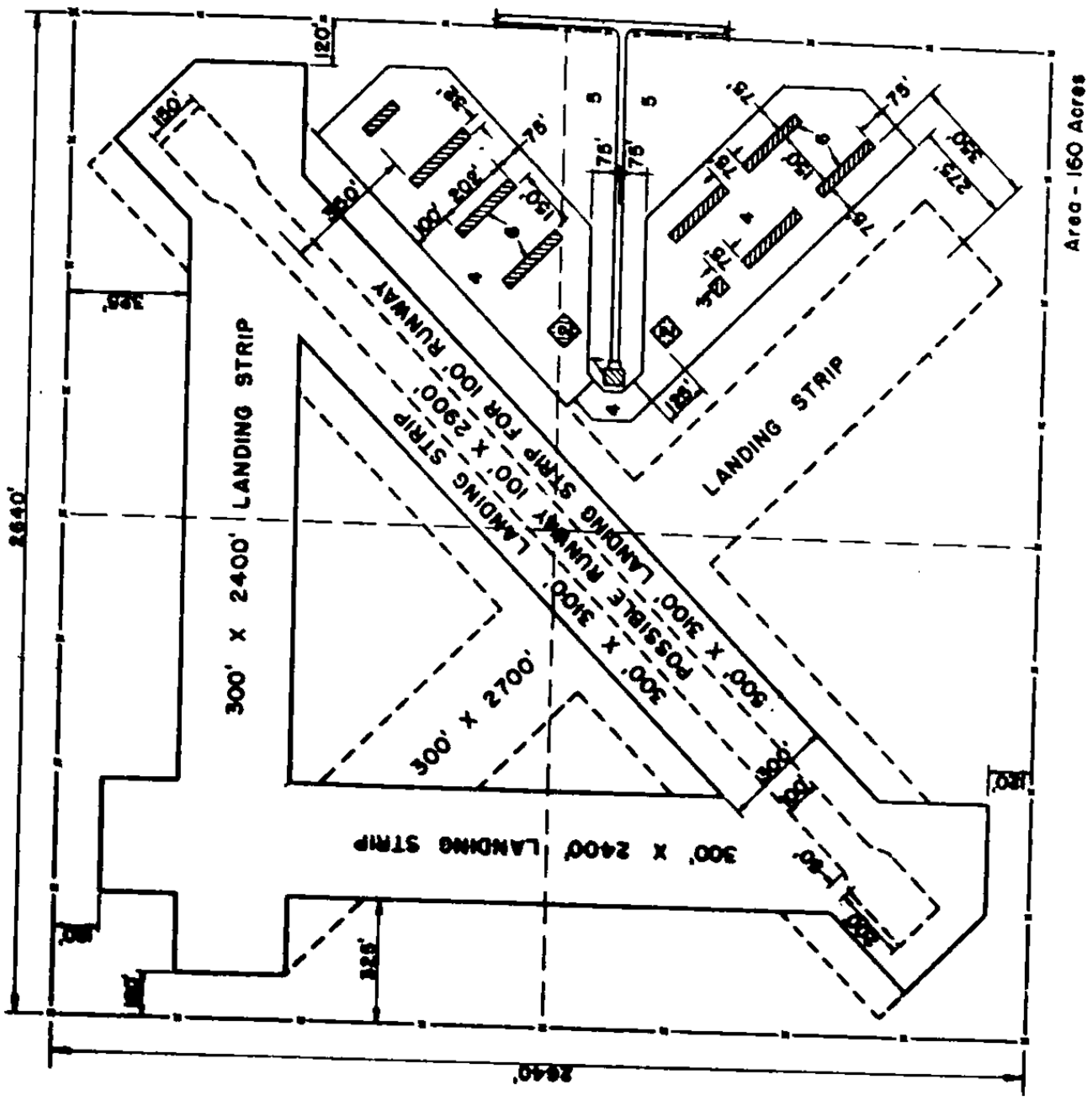
- Class I Development.
- Class II "
- Class IV "
- Ultimate "

Increase 5000' runways to 5500' for Class V Airport.

CLASS IV AIRPORT - TRIANGULAR RUNWAY ALIGNMENT.*
AREA REQUIRED = 1 SQ. MILE.
STAGE DEVELOPMENT SHOWN.

* Adapted from C.A.A.

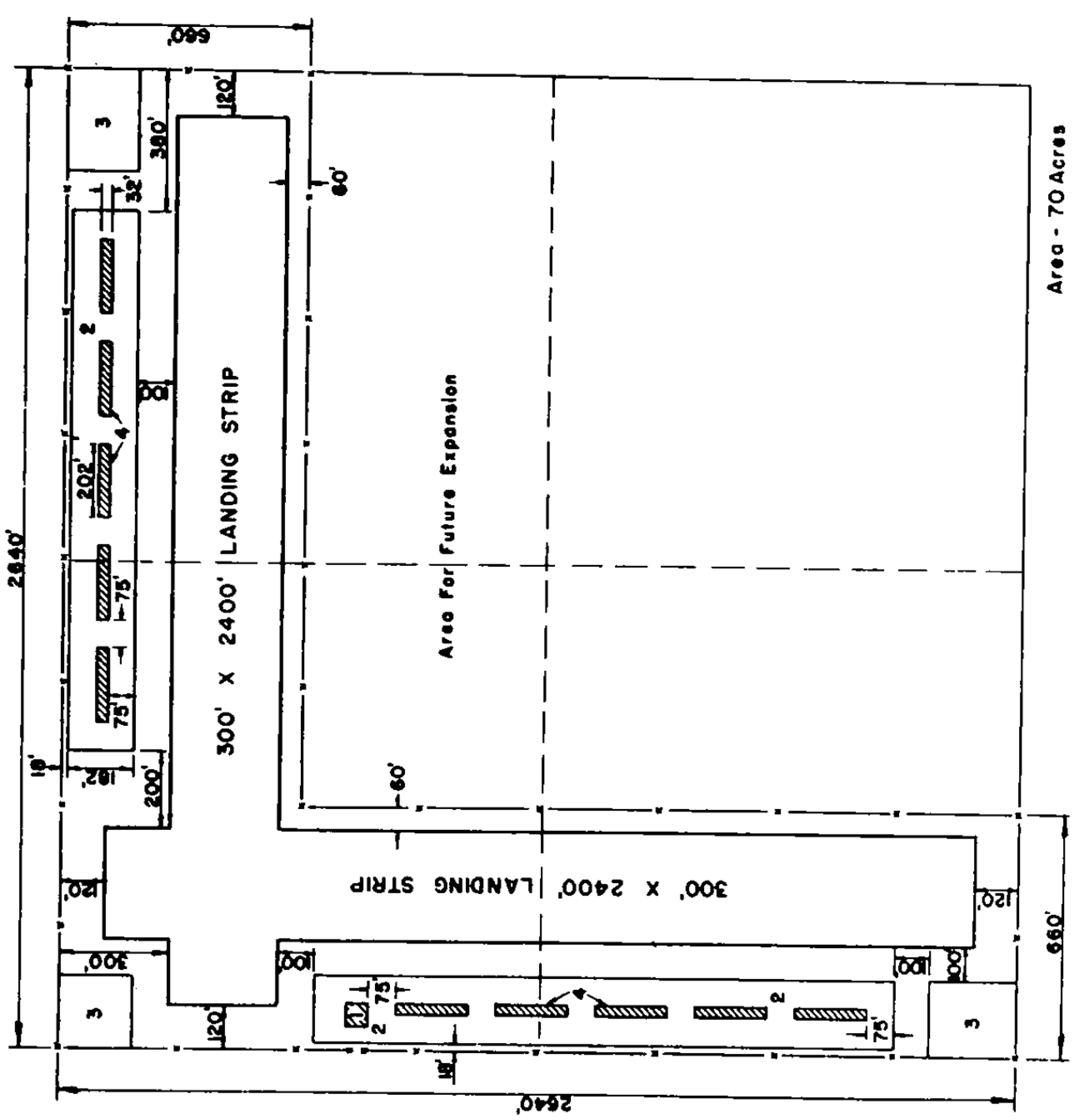
AIRPORTS — MASTER PLANS-3



LEGEND

1-Office
2-Shop & Hangar
3-Shop
4-Apron
5-Parking Area - Auto
6-Multiple Unit Hangars - Capacity 6 Planes Each

CLASS II AIRPORT*
L-LAYOUT WITH ADDITIONS

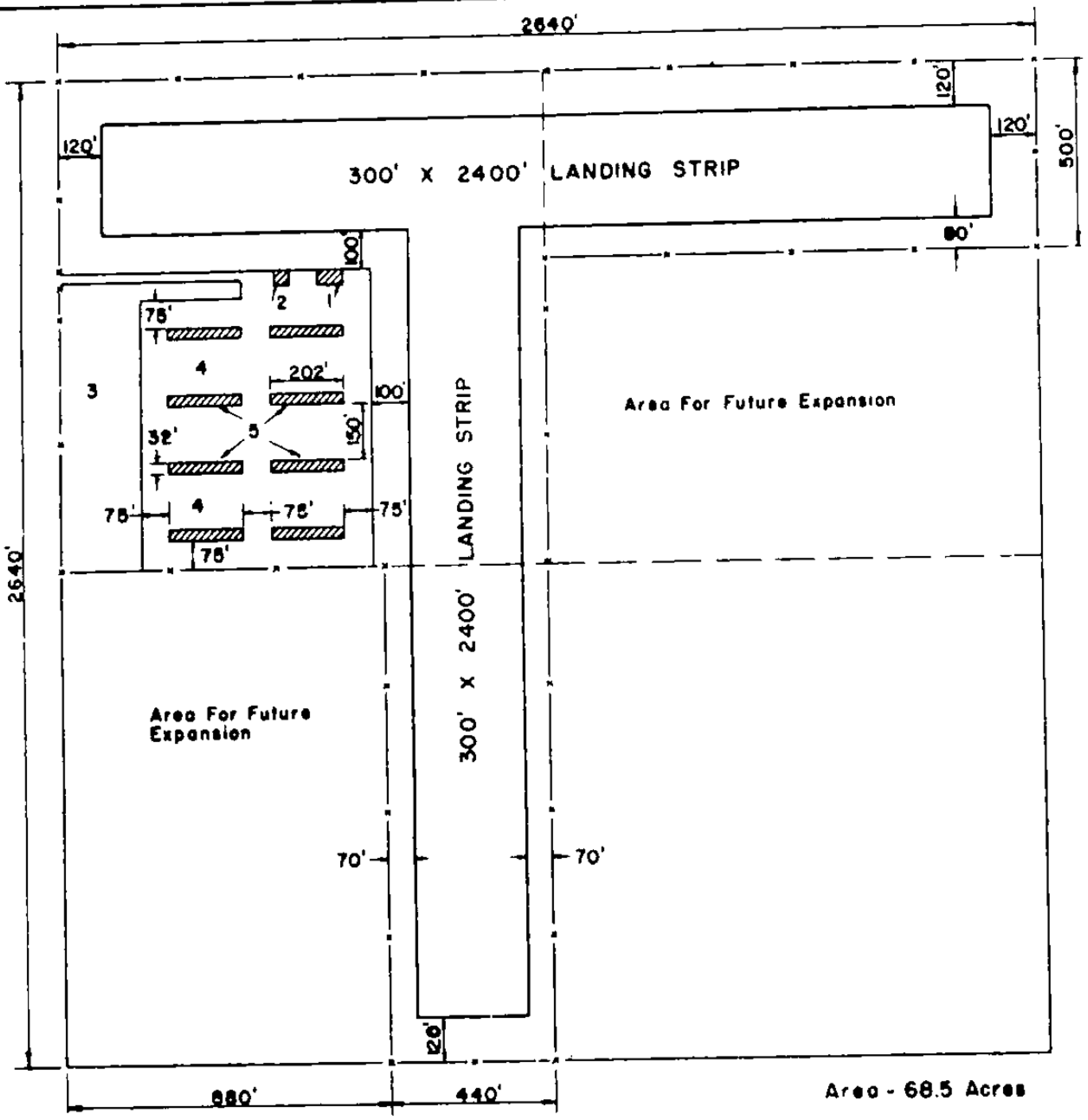


LEGEND

1-Office, Shop & Hangar
2-Apron
3-Parking Area - Auto.
4-Multiple Unit Hangars - Capacity 6 Planes Each

CLASS I AIRPORT *
L - LAYOUT

* Adapted from C.A.A.

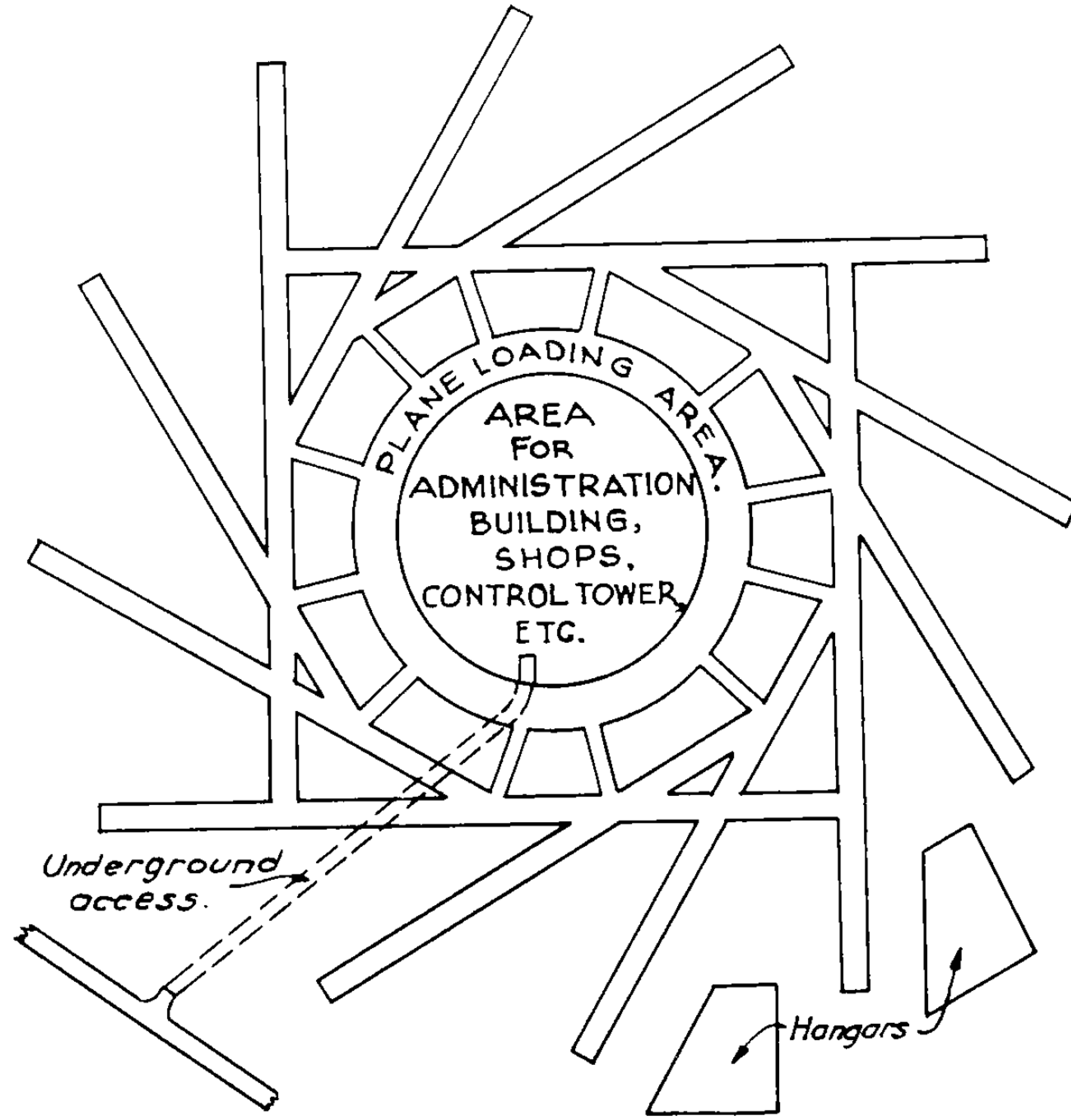


LEGEND

1-Office & Hangar
2-Shop
3-Parking Area-Auto.
4-Apron
5-Multiple Unit Hangars - Capacity 6 Planes Each

CLASS I AIRPORT *
T - LAYOUT

* Adapted from C.A.A.

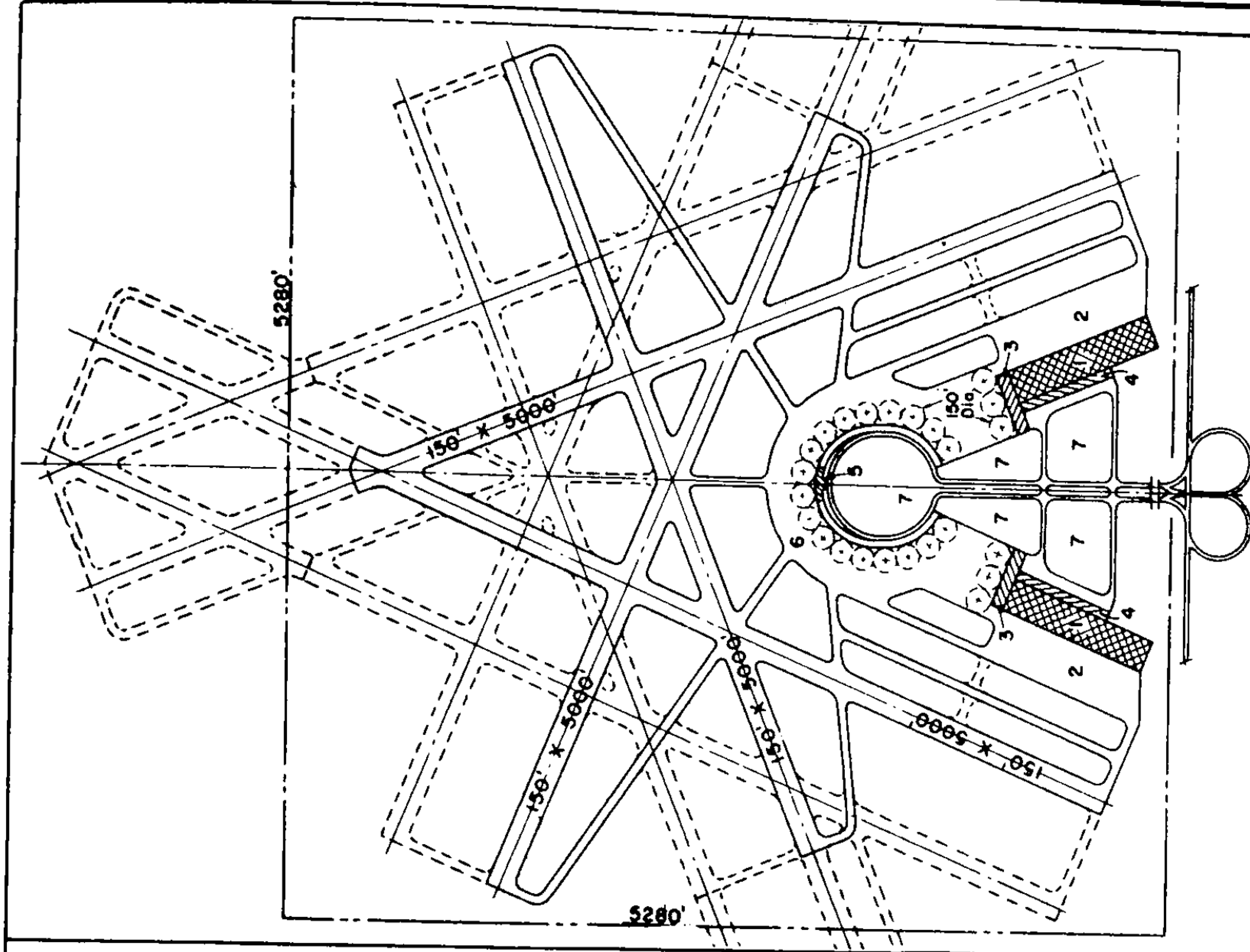


12 RUNWAY TANGENTIAL AIRPORT.

PROBABLE CAPACITY-240 PLANE MOVEMENTS PER HR.

Tangential schemes first proposed by Hans Lubig for terminal airports. Advantages over parallel runway schemes - maximum plane movements per hour, least taxiing time, max. safety by wide separation of landings and take-offs. Possible disadvantage, high initial cost due to large area of land required.

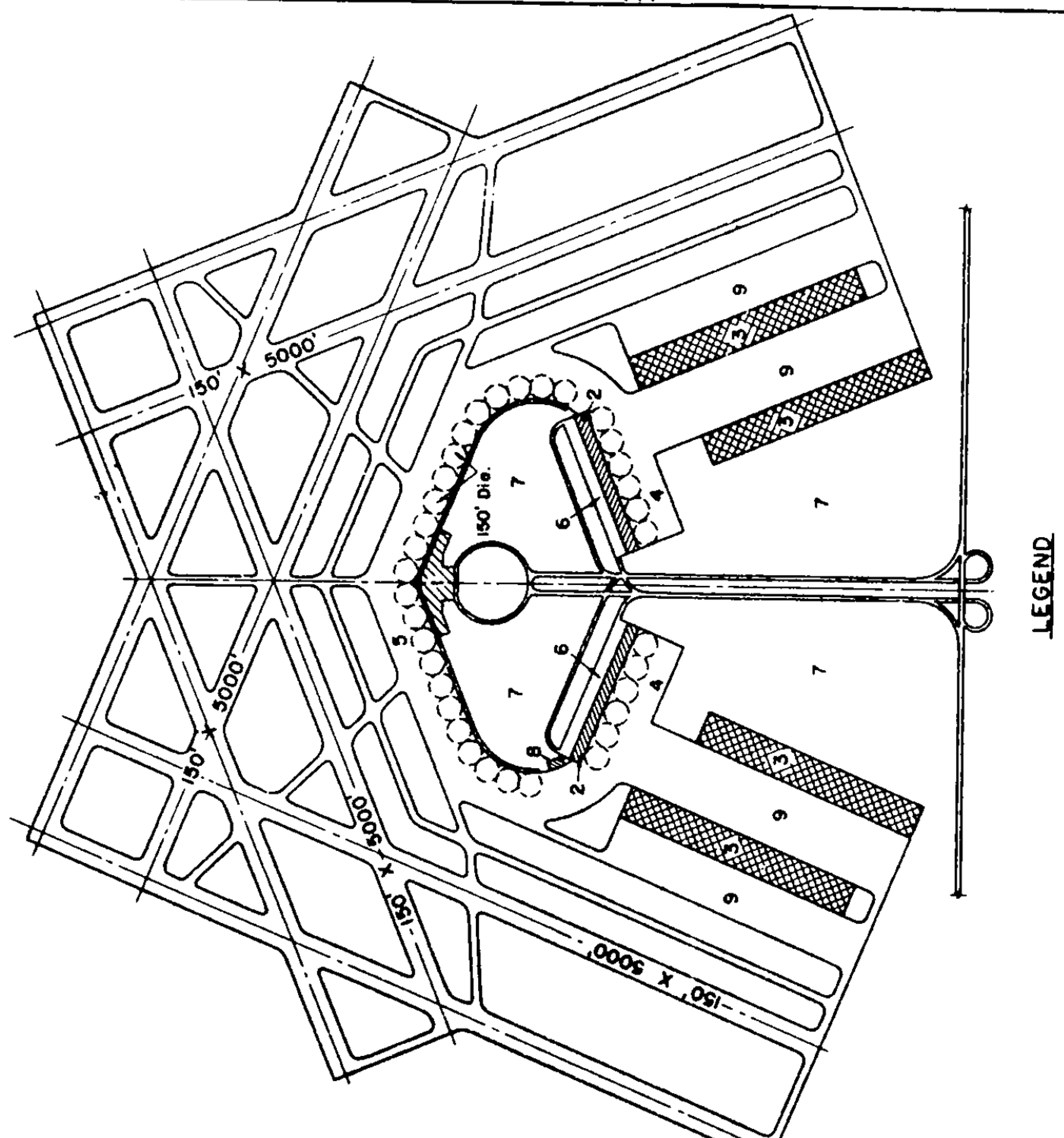
AIRPORTS — MASTER PLANS-5



LEGEND

1- Hangars
2- Hangar Aprons
3- Freight & Express Building
4- Truck Platform
5- Administration Building
6- Passenger Loading Apron
7- Parking Areas - Auto

CLASS IV AIRPORT - SOLID LINES*
CLASS V AIRPORT - DOTTED LINES*



LEGEND

1- Administration Building
2- Freight & Express Building
3- Hangars
4- Freight Loading Apron
5- Passenger Loading Apron
6- Truck Pavement
7- Building & Auto Parking Area
8- Fire-fighting & Maintenance Building
9- Hangar Apron

CLASS IV AIRPORT*

* Adapted from C.A.A.

AIRPORTS - RIGID PAVEMENTS - 1

EMPIRICAL APPLICATION OF WESTERGAARD FORMULAS-

Interior slab loadings with large tire imprint.

Interior thickness of slab - t_i - taken directly from Fig. A curves after modulus of subgrade reaction "k" has been determined by formula $k = \frac{Psi}{D}$ where Psi is load intensity in lbs. per sq. in. causing a subgrade deflection "D" of .05" of a rigid 30" diameter test bearing plate. The determination of "Psi" and "D" is generally called the "Field load Bearing Test". Test can be made with 2 loaded trucks, a 14" by 20' I beam between them, a 30" bearing plate on the subgrade, a hydraulic jack between the plate and I beam and Ames gauges to read deformations when the jack is operated. Approximate values of K are given on Pg. 3-08. See Pg. 3-17 for frost protection requirements. C.A.A. recommends pavement thickness increased at end of runways and under taxiways crossing runways. See Fig. C & D Pg. 4-28.

Edge thickness - t_e - for free edges and free (undoweled) expansion joints is generally designed as 1.33 t_i to 1.5 t_i. Edges not subject to runover such as taxiways and aprons are often not thickened. C.A.A. recommends t_e = 8" if t_i less than 8"; $t_e = t_i$ for t_i 8" and over.

Wheel load for design: For runways use 1/2 of recommended gross plane wt. See Pg. 4-15. Do not increase due to dynamic loading and landing impact stress. For turnarounds, aprons, hardstandings, taxiways and other areas subject to high shearing stresses due to locked wheel turning and dynamic stress due to motor warm up, increase wheel loads by 25%.

Concrete working stress: - 28 day flexural strength (Modulus of Rupture) divided by 1.75 for normal operation and by 1.40 for limited operation. Pavements designed for limited operation not to be those subject to dynamic loading. Flexural strength equals about 1/6 compressive strength. An economical paving Concrete would be 700 p.s.i. flexure strength and 4500 p.s.i. compressive strength max. water-cement ratio of 5 1/2 and Cement factor (bags per Cu. yd.) of not less than 6.

Pavement Details : See Pg. 4-27 & 28.

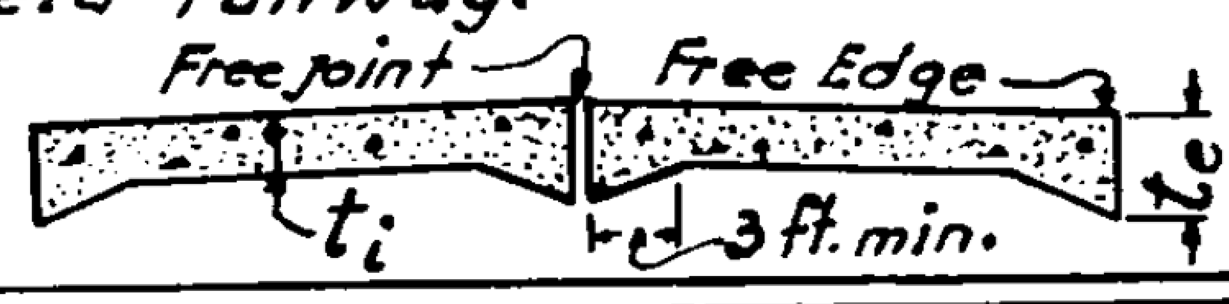
DESIGN EXAMPLE: Given: Subgrade modulus of reaction K of 300. Wheel load of 37,000 lb., Design factor of 1.75 (normal operation). Concrete of 700 lb. flexural strength.

Required: Interior and edge thickness for Airfield runway.

Solution: Working stress = 700/1.75 = 400 lb./sq. in.

Interior slab thickness t_i from curves is 6 inches.

Free edge thickness - t_e = 1.5 t_i = 9 inches.



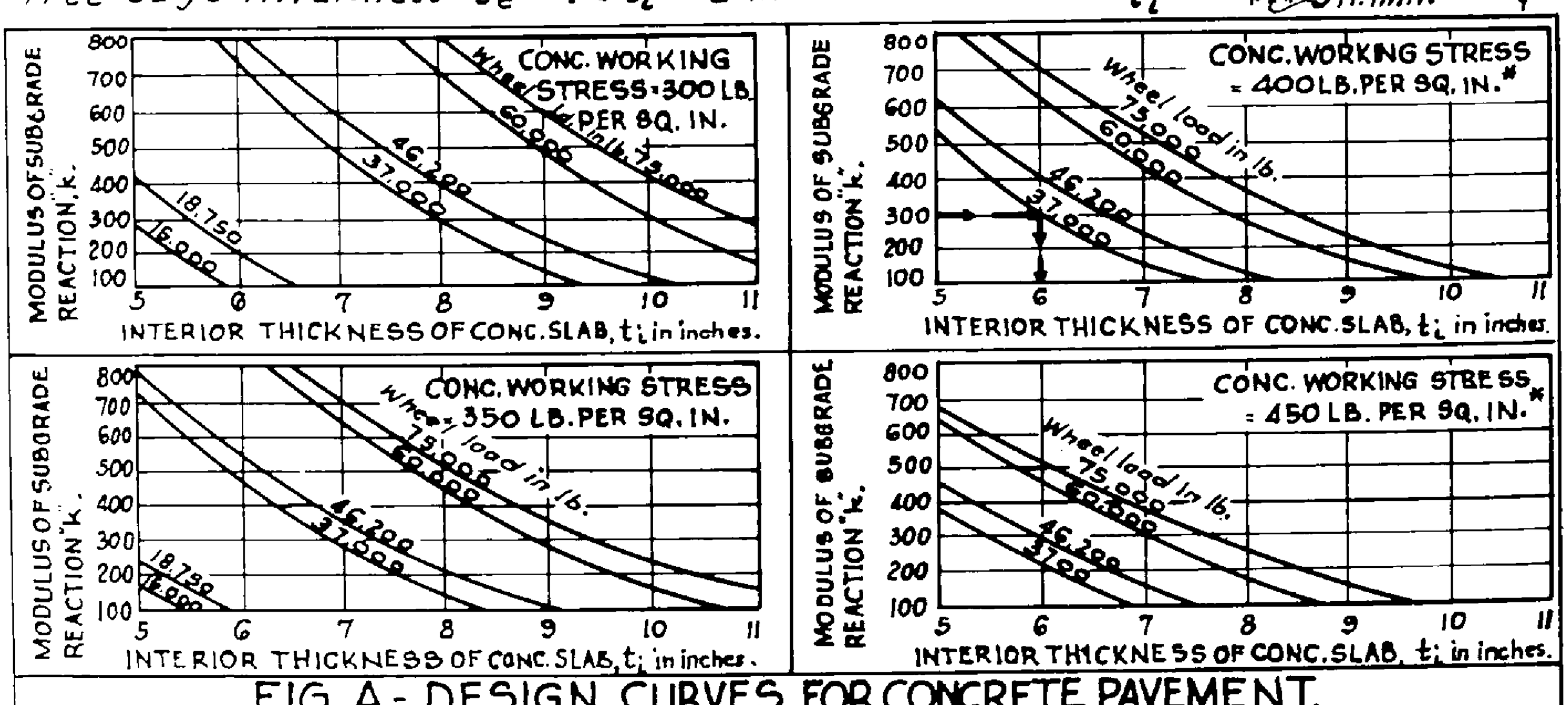


FIG. A - DESIGN CURVES FOR CONCRETE PAVEMENT.

*Adopted from Military Airfields by Col. James H. Stratton, Corps of Engineers, in Jan. 1944 Proceedings of A.S.C.E.

AIRPORTS - RIGID PAVEMENTS - 2 *

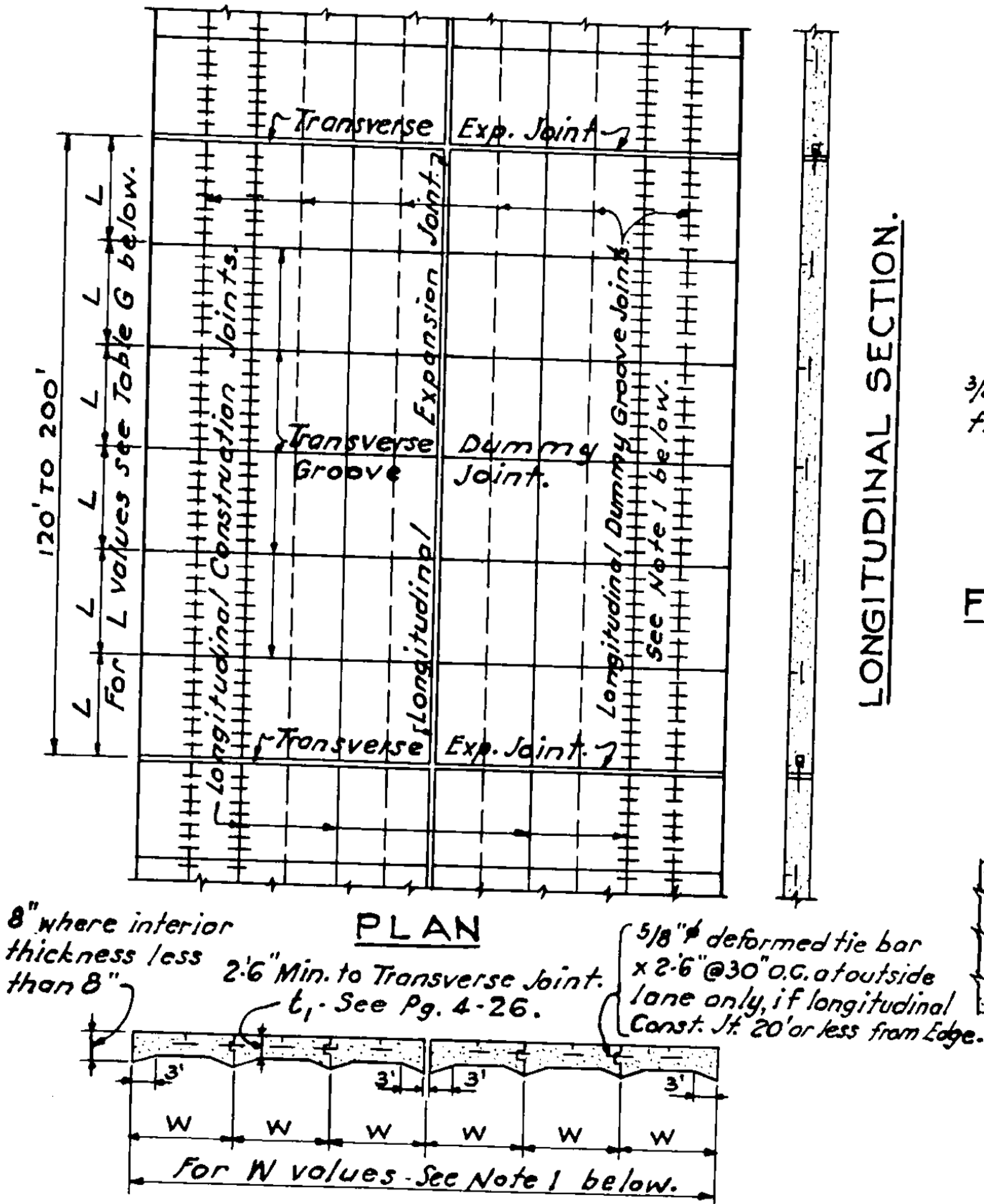


FIG. A - RUNWAY LAYOUT.

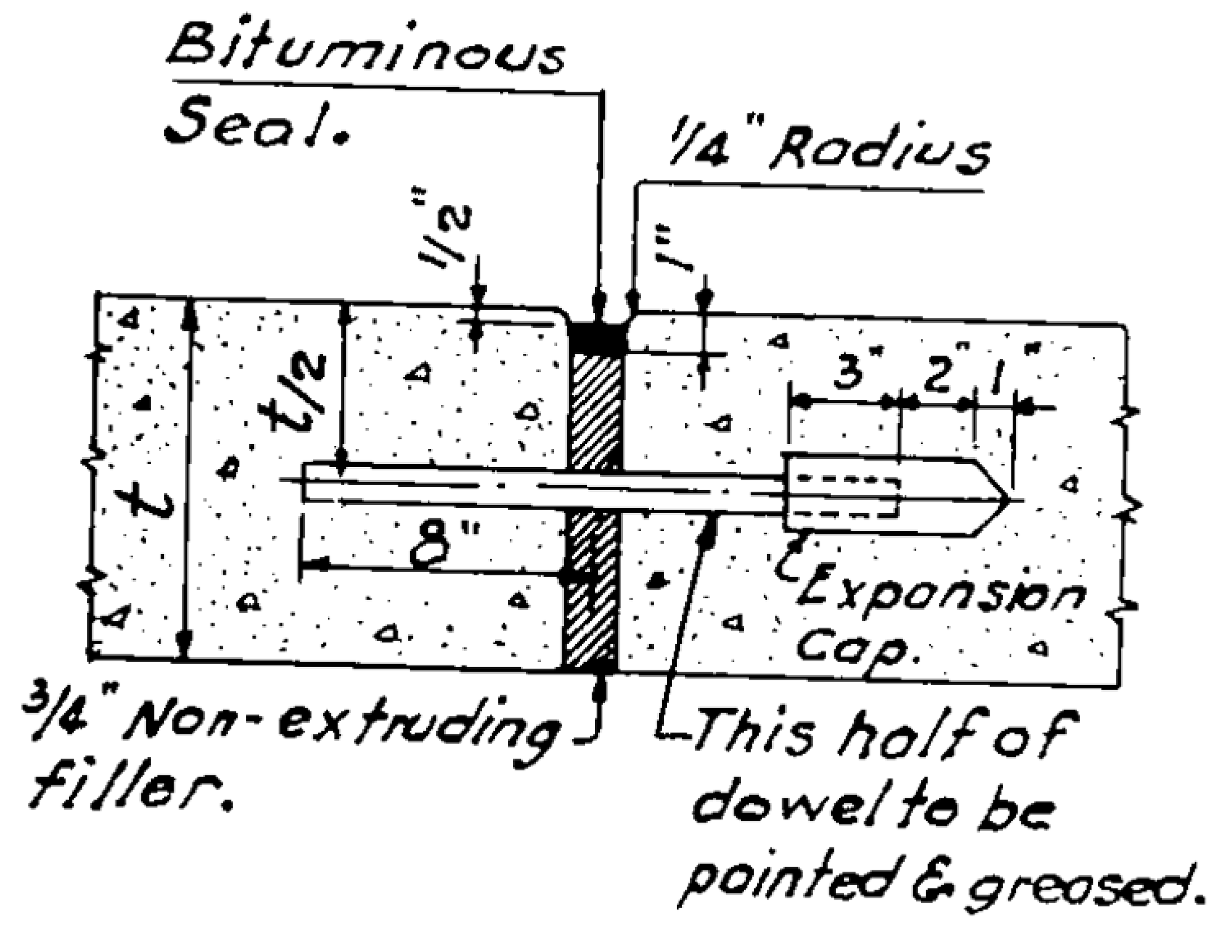


FIG. B - TRANSVERSE EXPANSION JOINT.

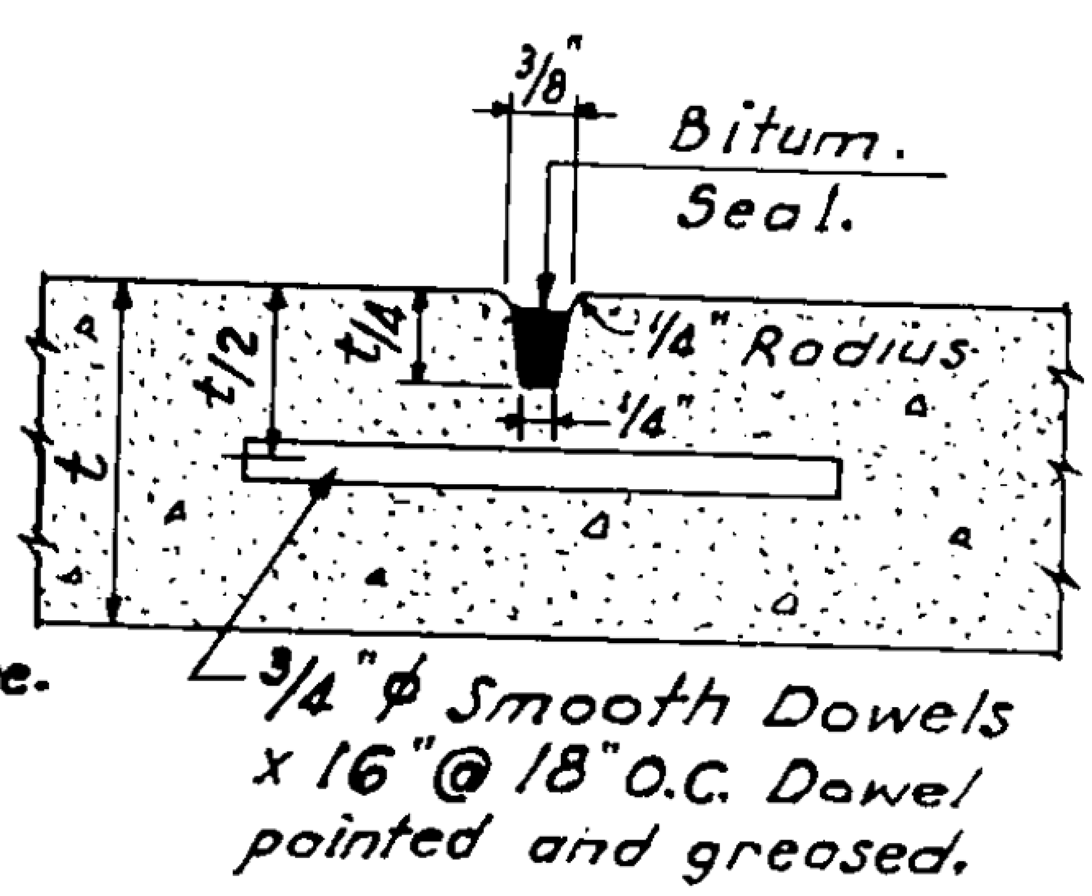


FIG. C - TRANSVERSE DUMMY GROOVE JOINT.

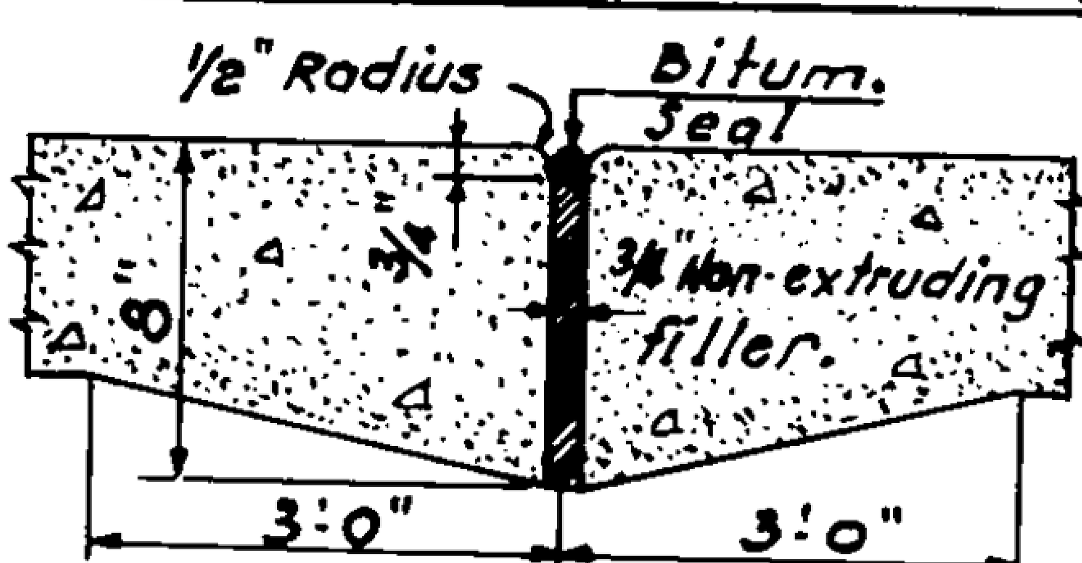


FIG. D - LONGITUDINAL EXPANSION JOINT.

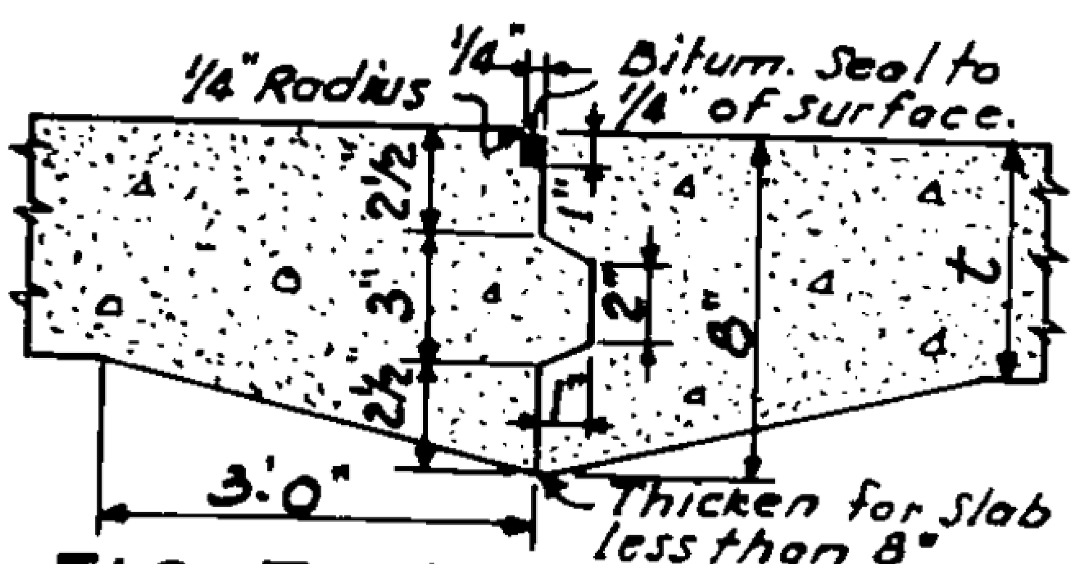


FIG. E - LONGITUDINAL CONSTRUCTION JOINT.

Same as Transverse Dummy Groove Joint, except use 5/8"φ deformed tie bars x 2'-6" @ 30" o.c. instead of smooth 3/4" dowels.

FIG. F - LONGITUDINAL DUMMY GROOVE JOINT.

TABLE G - TRANSVERSE DUMMY GROOVE JOINT SPACING - (L).

COARSE AGGREGATE	VALUE OF L
Crushed Granite	25'
Crushed Limestone and Calcareous Gravel.	20'
Siliceous Gravel and Slag.	15'

NOTE 1:

Selection of W values depends on paving equipment available for job. Pavers are made for W = 10', 12'-6", 15', 16'-8", 20', 25', 30'. 25' is recommended W value. Where W is less than 20', omit longitudinal Dummy Groove Joint.

* All details in accordance with C.A.A. requirements.

AIRPORTS - RIGID PAVEMENTS*- 3

LEGEND FOR FIG. A & B - FOR JOINT DETAILS - See Pg. 4-27.

- *Longitudinal Expansion Joint.*
- *Longitudinal Construction Joint.*
- *Longitudinal Dummy Groove Jt.*
- *Transverse Expansion Joint.*
- *Transverse Dummy Groove Joint.*

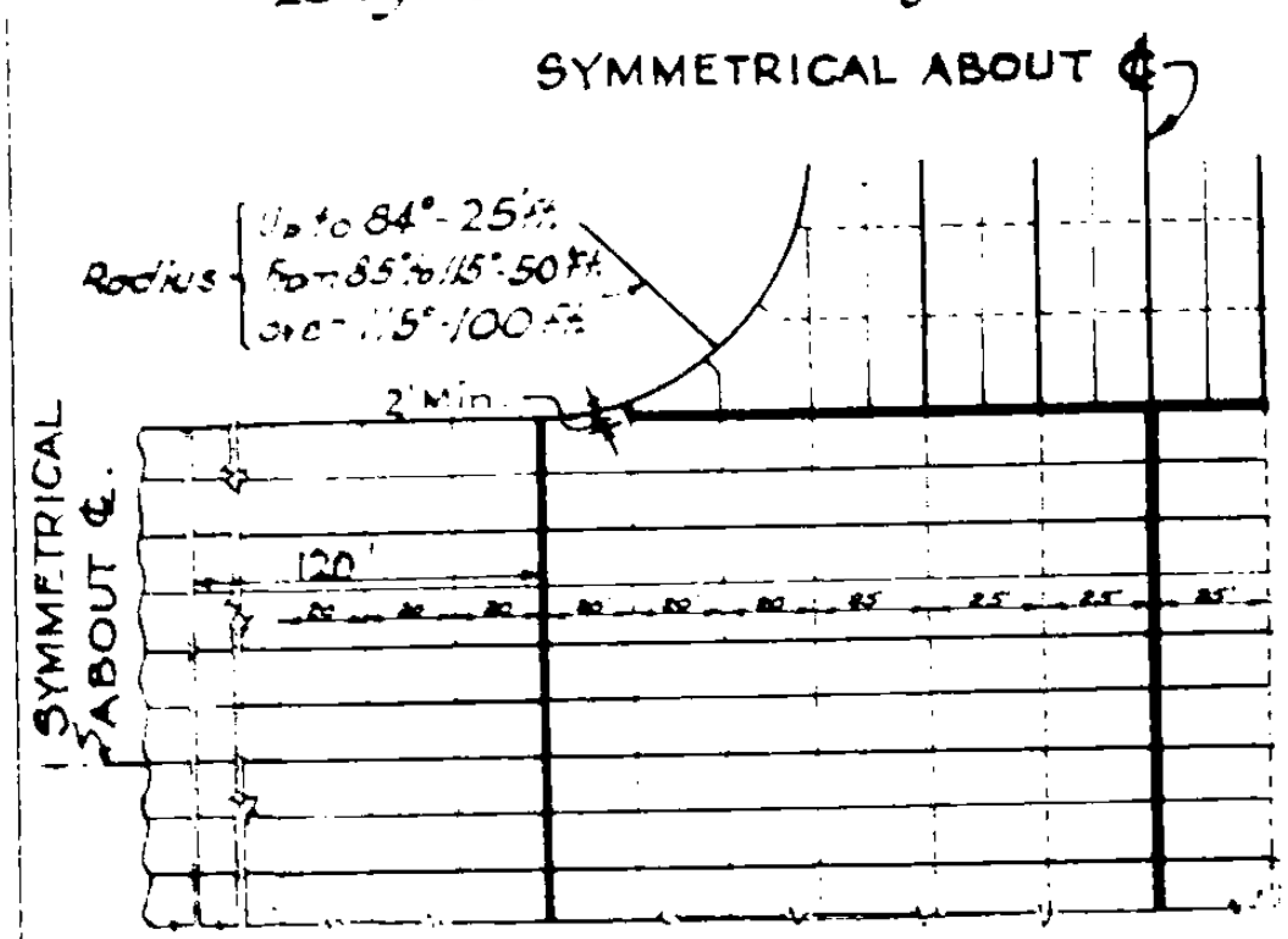


FIG. A - 1/4 JOINTING PLAN RUNWAYS AT RIGHT ANGLES.

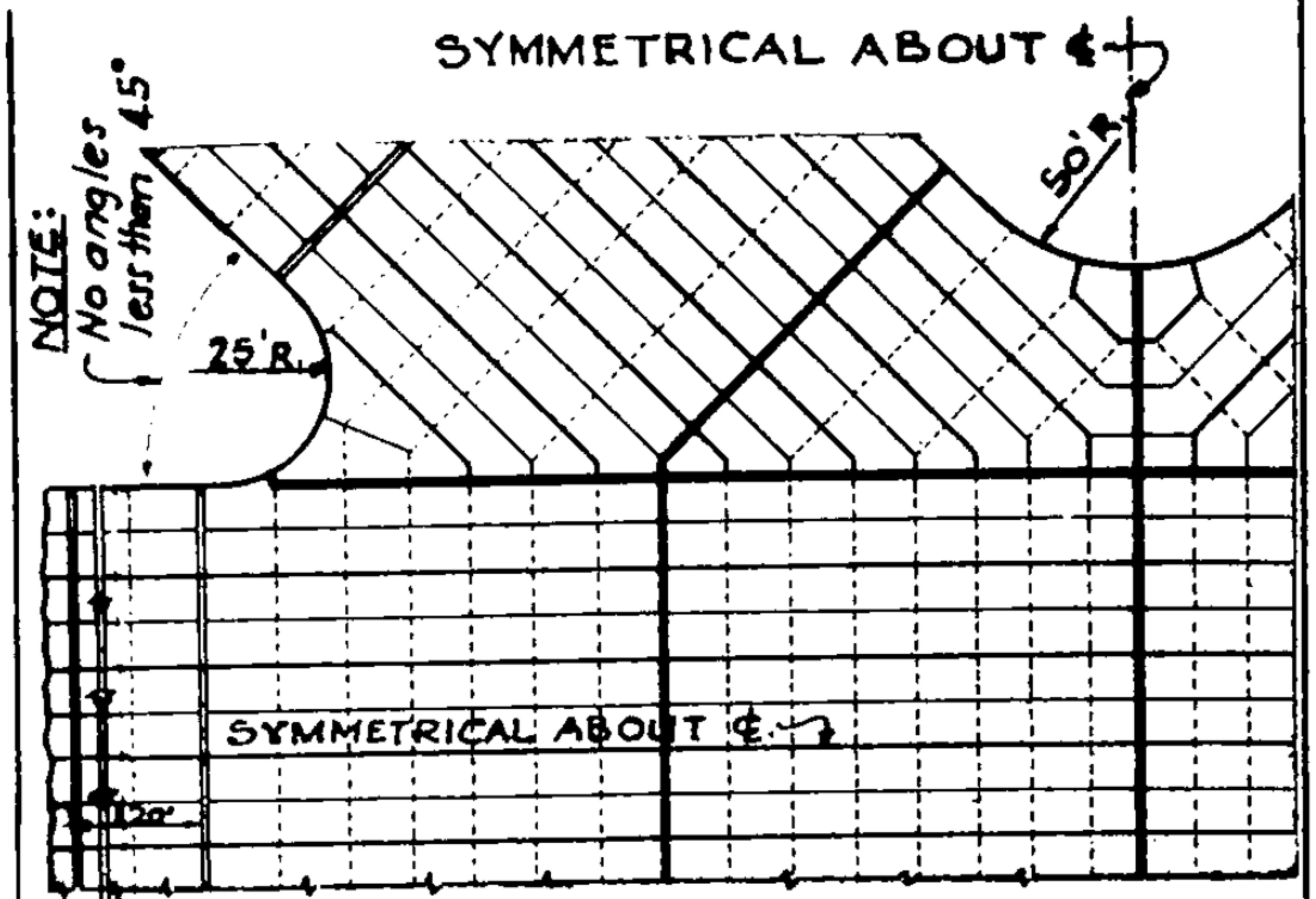


FIG. B - 1/4 JOINTING PLAN 3 RUNWAYS.

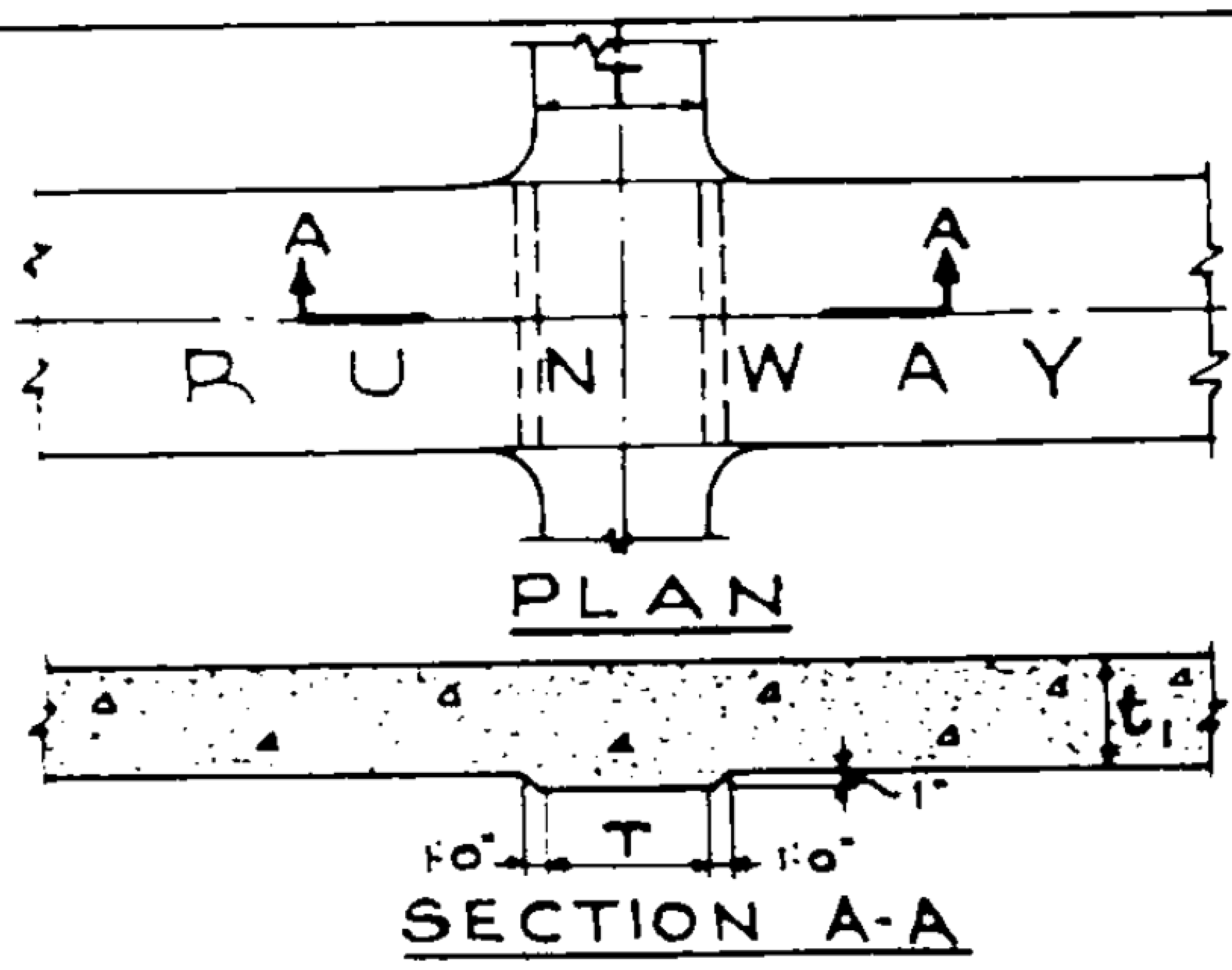


FIG. C - INCREASED DEPTH WHERE TAXIWAY CROSSES R.W.

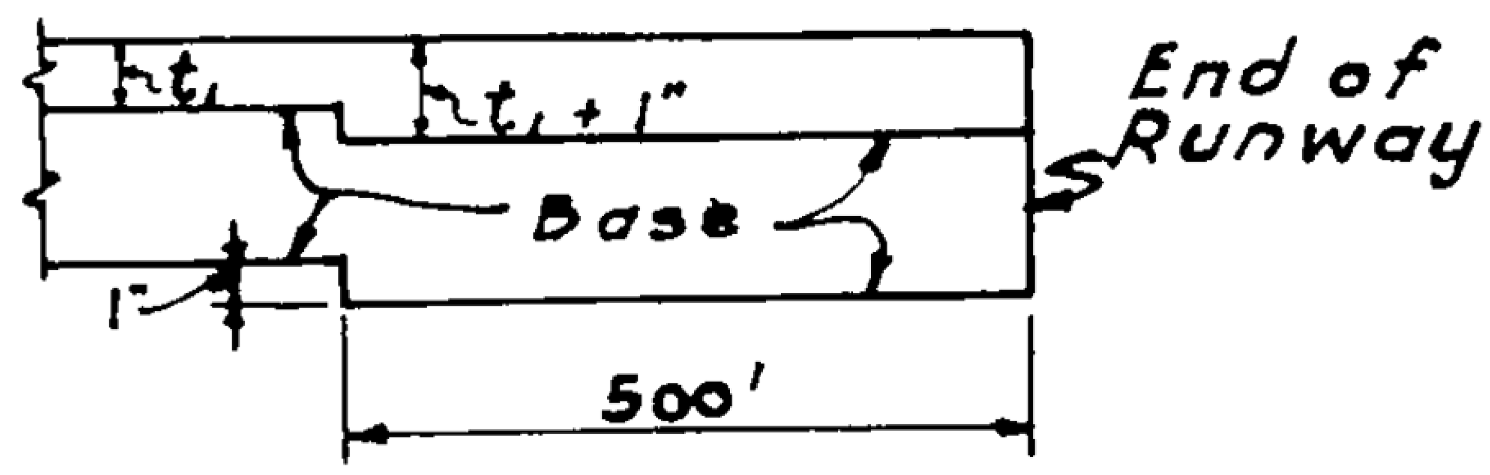


FIG. D - INCREASED DEPTH AT END OF RUNWAYS.

* *All details in accord with C.A.A. requirements.*

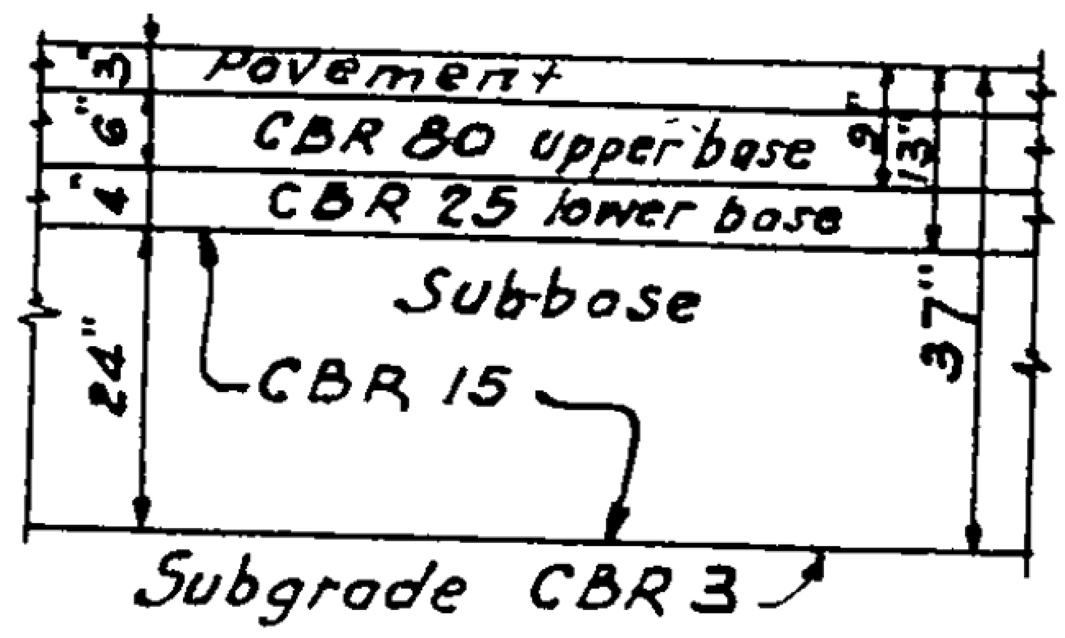
AIRPORTS - FLEXIBLE PAVEMENTS-1

APPLICATION OF CALIFORNIA BEARING RATIO (CBR) METHOD OF DESIGN.

COMBINED THICKNESS of pavement base and subbase taken from Fig. A when CBR of subgrade is known. Determination of CBR consists of testing a compacted sample of soil at optimum moisture content and maximum density in a 6" diameter cylinder with a 3 sq. inch area circular piston. Enough load is applied to deflect the sample at rate of .05 inch per minute to a total deflection of .50 inch; the load is measured and stated in ratio to that supported by crushed stone under the same conditions. The same test is applied after the sample is allowed to soak for four days- the ratio obtained at the second test is the CBR. Approximate values of CBR are given on Pg. 3-08. For pavement areas subject to limited operations, the combined thickness may be reduced 20%. CAA recommends combined thickness be increased 20% for taxiways, runways used extensively as taxiways, and for a length of 500 ft. at ends of all runways; the increase to be provided by additional subbase thickness, or base thickness where there is no subbase. CAA also recommends an increase at ends of runways and adjacent taxiways for a 200 ft. length in surface course of 1/2 inch if a 2 inch surface is provided.

PROPORTIONING COMBINED THICKNESS INTO PAVEMENT BASE AND SUBBASE: See example below for method. Where materials available for base course vary widely as to CBR the selection of which materials to use may be based on a cost analysis of several alternate designs. The total thickness required over a given subgrade will always be the same wheel loads for design. use 1/2 of recommended gross plane weight. See Pg. 4-15. Typical Sections - See Pg. 4-30.

DESIGN EXAMPLE: *Given*: 37,000 lb. wheel load, Subgrade of CBR 3, Sub-base material of CBR 15, lower base material of CBR 25 & upper base material of CBR 80.
Required: Thickness of pavement and Base layers.
Solution: (See Fig. A).
Step 1. - Thickness over subgrade of CBR 3 is 37".
Step 2. - Thickness over base of CBR 15 is 13".
Step 3. - Thickness over base of CBR 25 is 9".
(6" of 80% base & 3" of Pavement, Tables B & C.)



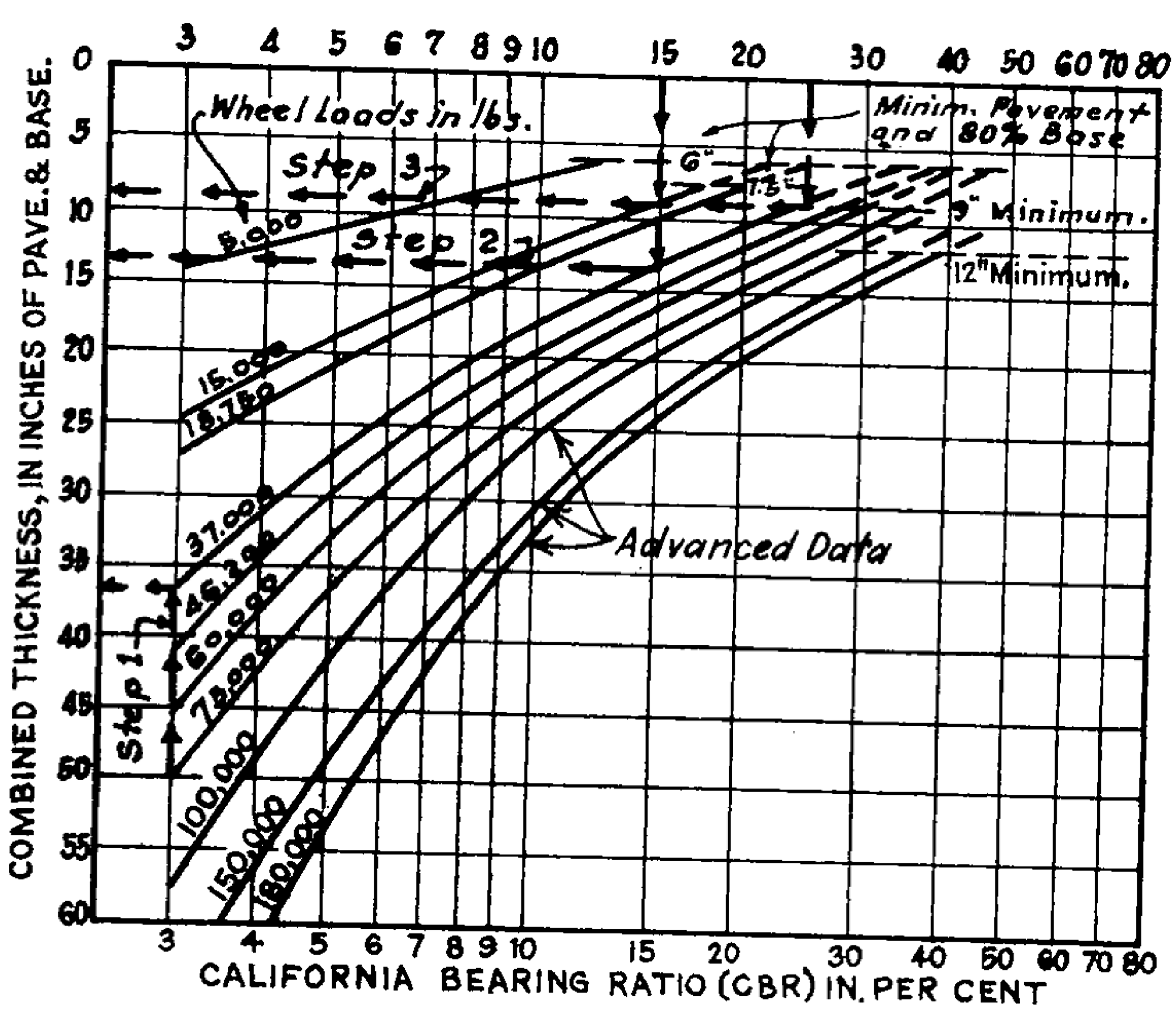


FIG. A - CURVES FOR THE DESIGN OF FLEXIBLE PAVEMENTS.*

TABLE B-PAVEMENT THICKNESS*

Central plant hot-mix Bituminous Concrete preferred for normal use.

DESIGN WHEEL LOAD	PAVEMENT THICKNESS.
Up to 15,000 lbs.	Min. 1 1/2 inches
to 37,000 lbs.	Min. 3 inches
over 37,000 lbs.	In accordance with each case, but in general not over 6".

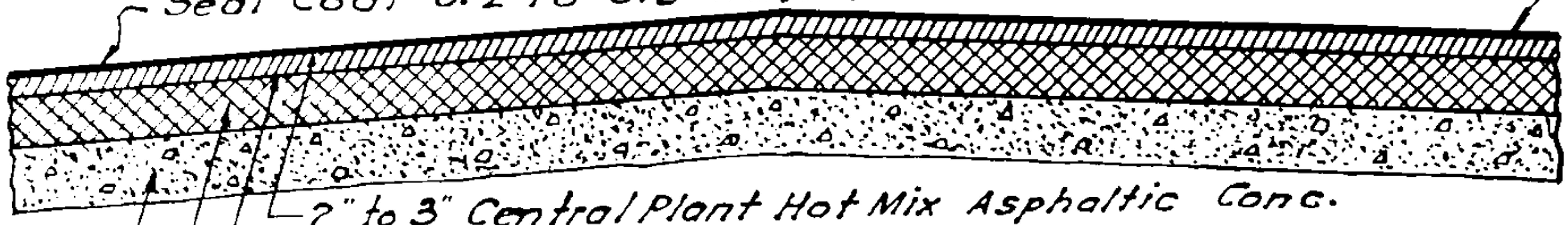
TABLE C - MINIMUM ALLOWABLE CBR UPPER 6" OF BASE COURSE.*

GROSS WEIGHT OF PLANE	MINIMUM CBR.
10,000 to 30,000 lbs.	50
30,000 to 74,000 lbs.	65
74,000 to 120,000 lbs.	80

Tentatively established for use when CBR 80 material is not locally available and importation is impracticable. Base material of less than CBR 80 should not be used directly under a pavement when subgrade soil is plastic.

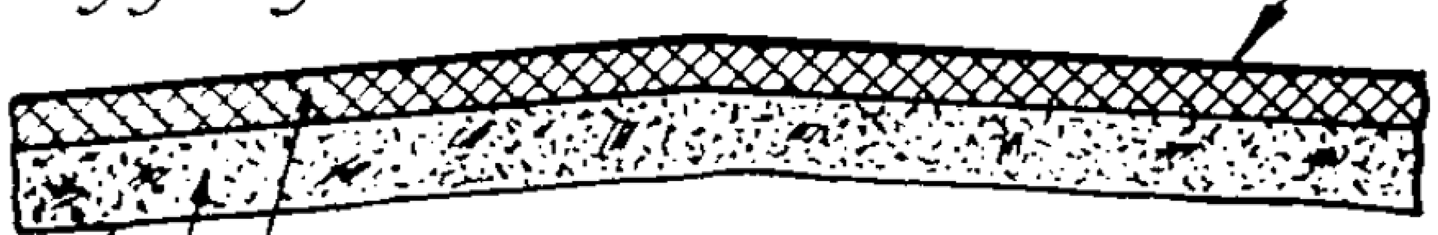
*Adapted from Military Airfields by Col. James H. Stratton, Corps of Engineers in Jan. 1944 Proceedings of the A.S.C.E.

AIRPORTS - FLEXIBLE PAVEMENTS-2



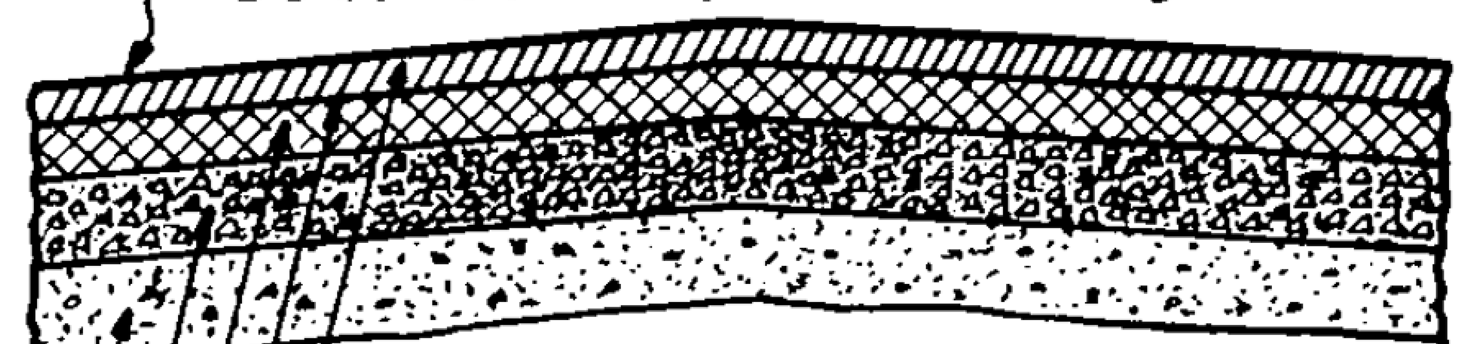
TYPICAL SECTION Nº 1

See Notes below.



TYPICAL SECTION Nº 2

See Notes below.



TYPICAL SECTION Nº 3

See Notes below.

NOTES: Typical sections subject to design analysis. See Table A below for Base Course Materials. Base courses may be mechanically stabilized or stabilized with bituminous, chemical or Portland Cement admixtures; generally imported materials required. Subgrades may have sufficient bearing value or be composed of select borrow on site.

Sect. 1 - Commonly used over entire United States.
Sect. 2 - Commonly used in Southern States. Base formed by adding sand or clay to clay or sand respectively at site or importing from local deposits.
Sect. 3 - Commonly used in New England and Mid-Atlantic States.

TABLE A - MATERIALS FOR BASE COURSES.*

MATERIAL / SECTION OF COUNTRY	GLACIAL GRAVEL	CLAY GRAVEL	CRUSHED STONE	SHALES	SLAGS	DISINTEGRATED GRANITE	SAND-CLAY	CHERT & LIME-STONE	CORAL ROCK	SHELL	LIME-ROCK	CALICHE
NEW ENGLAND	×	×	×									
MID-ATLANTIC		×	×	×	×							
SOUTH-ATLANTIC		×	×			×	×					
MIDDLE SOUTH		×			×		×	×				
FLORIDA							×		×	×	×	
GULF COAST			×							×		
SOUTH WEST		×	×									×
ROCKY MT. & WEST COAST		×	×									

NOTE: These materials have a satisfactory bearing value to be used for base courses and can be used alone or blended to give proper results. Mechanical, bituminous, chemical or Portland cement stabilization may be necessary to give required compaction.

*Adapted from Engineering Manual - War Dept., Corps of Engineers, June 1942.

AIRPORTS - PAVEMENT DETAILS

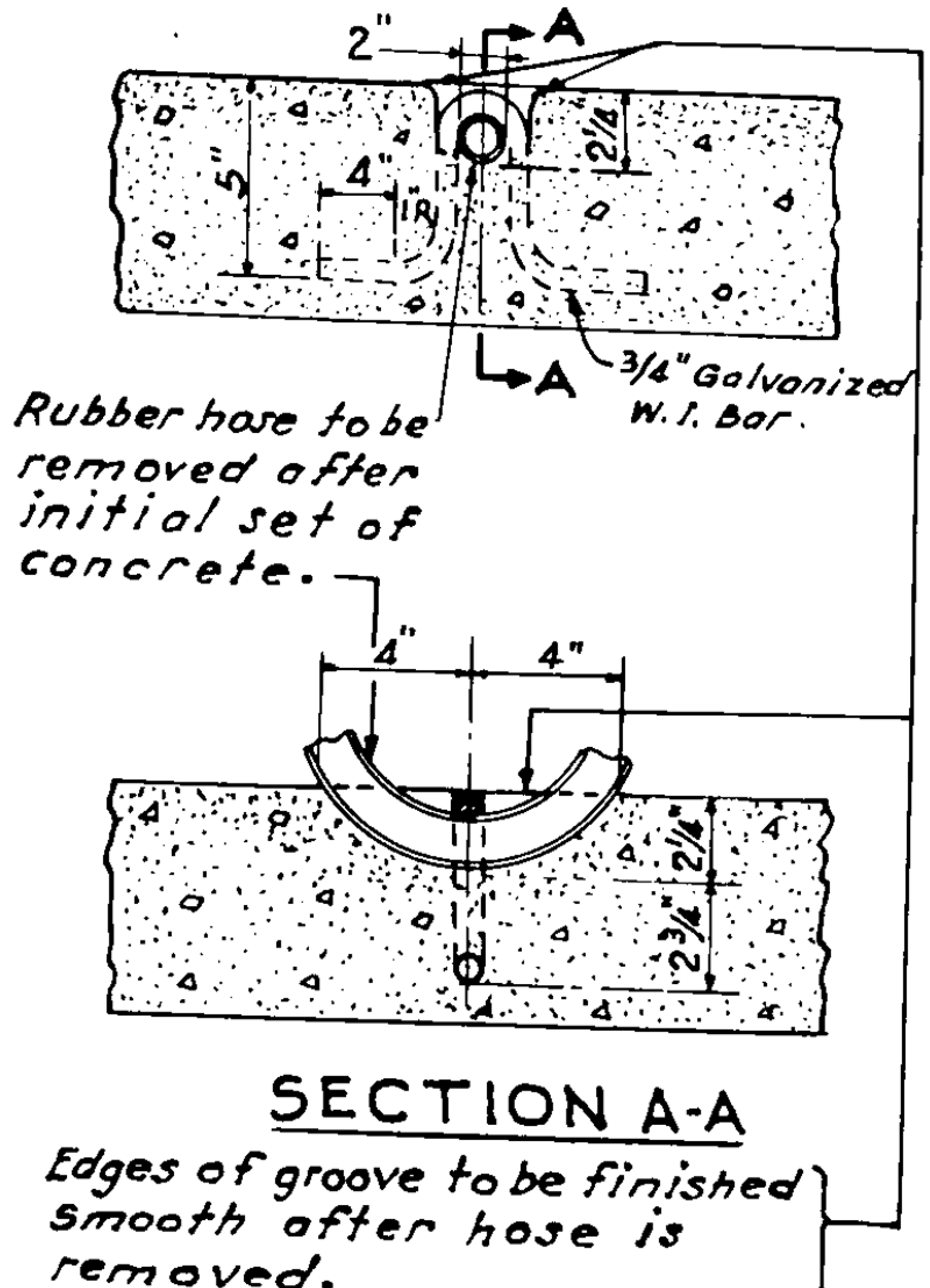


FIG. A - TIE DOWN ANCHOR FOR CONCRETE APRONS.*

PLACE ANCHORS AT 20' CENTERS BOTH WAYS IN WARM UP APRONS & PARKING AREAS.

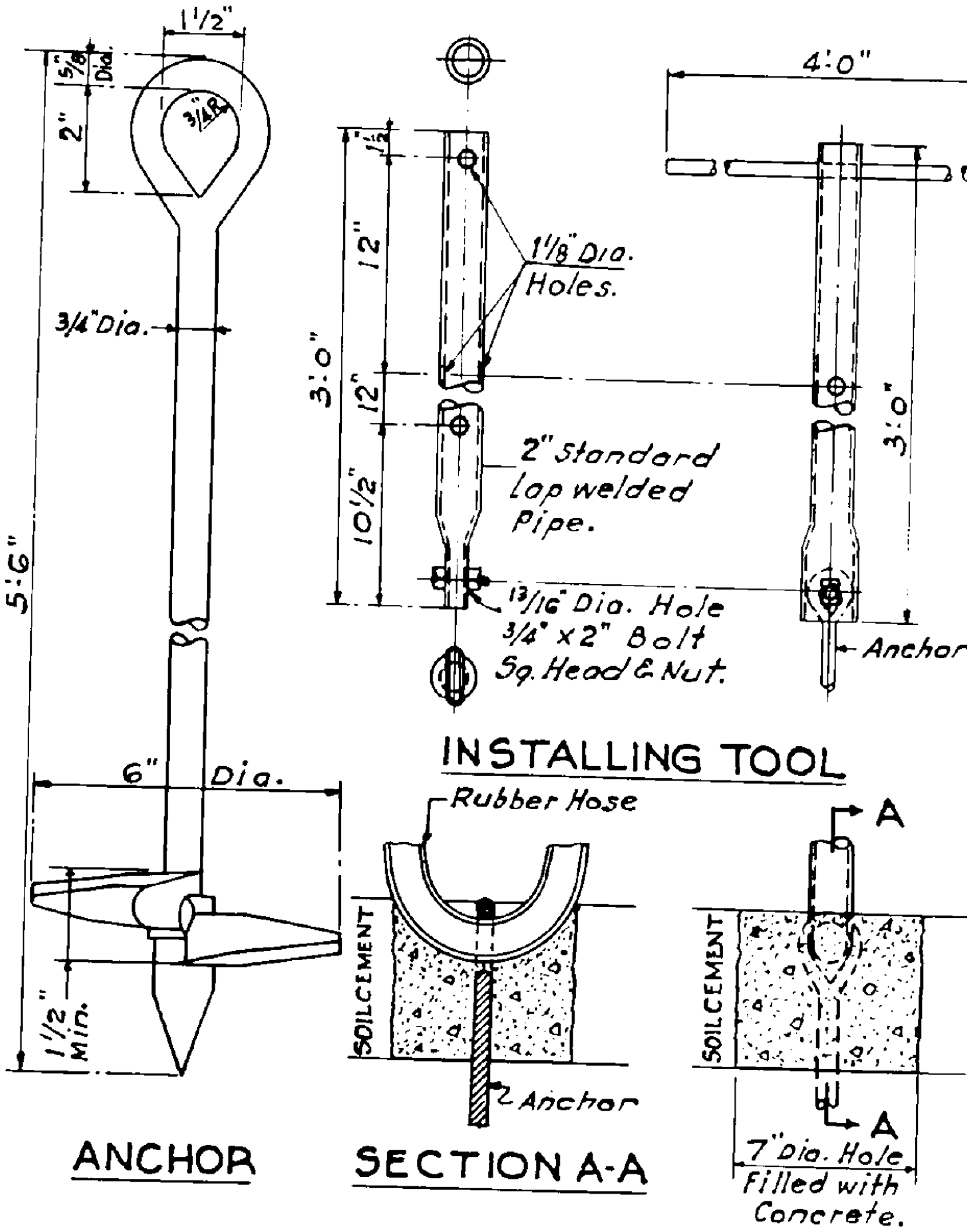


FIG. B - TIE DOWN ANCHORS FOR SOIL CEMENT & FLEXIBLE PAVEMENT APRONS.**

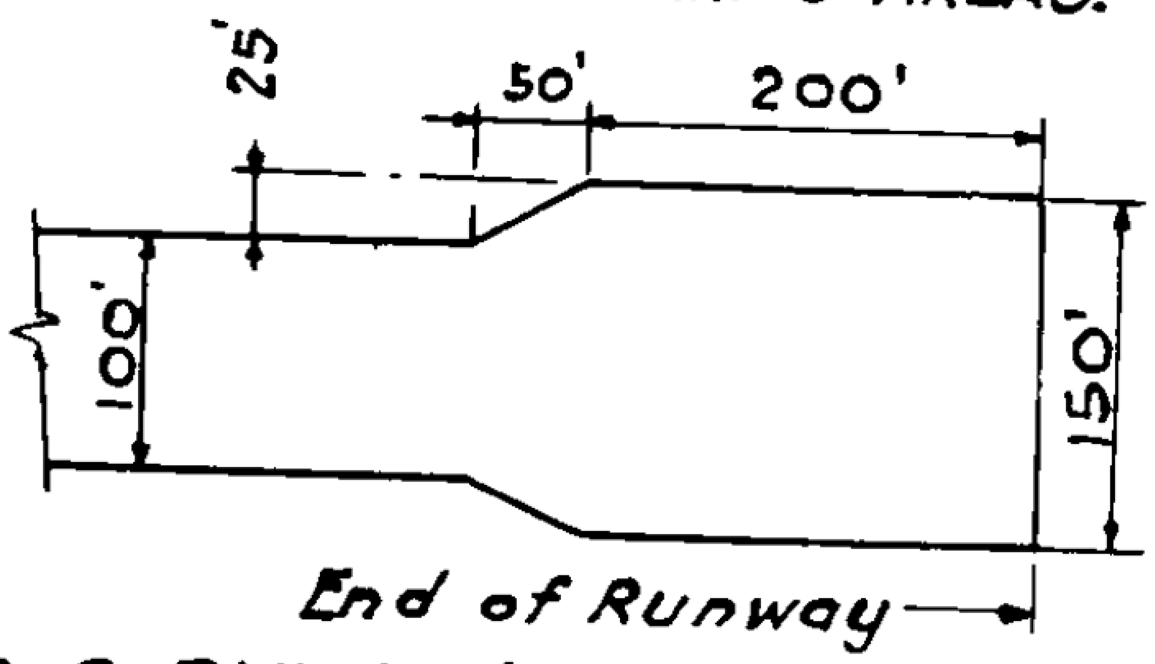
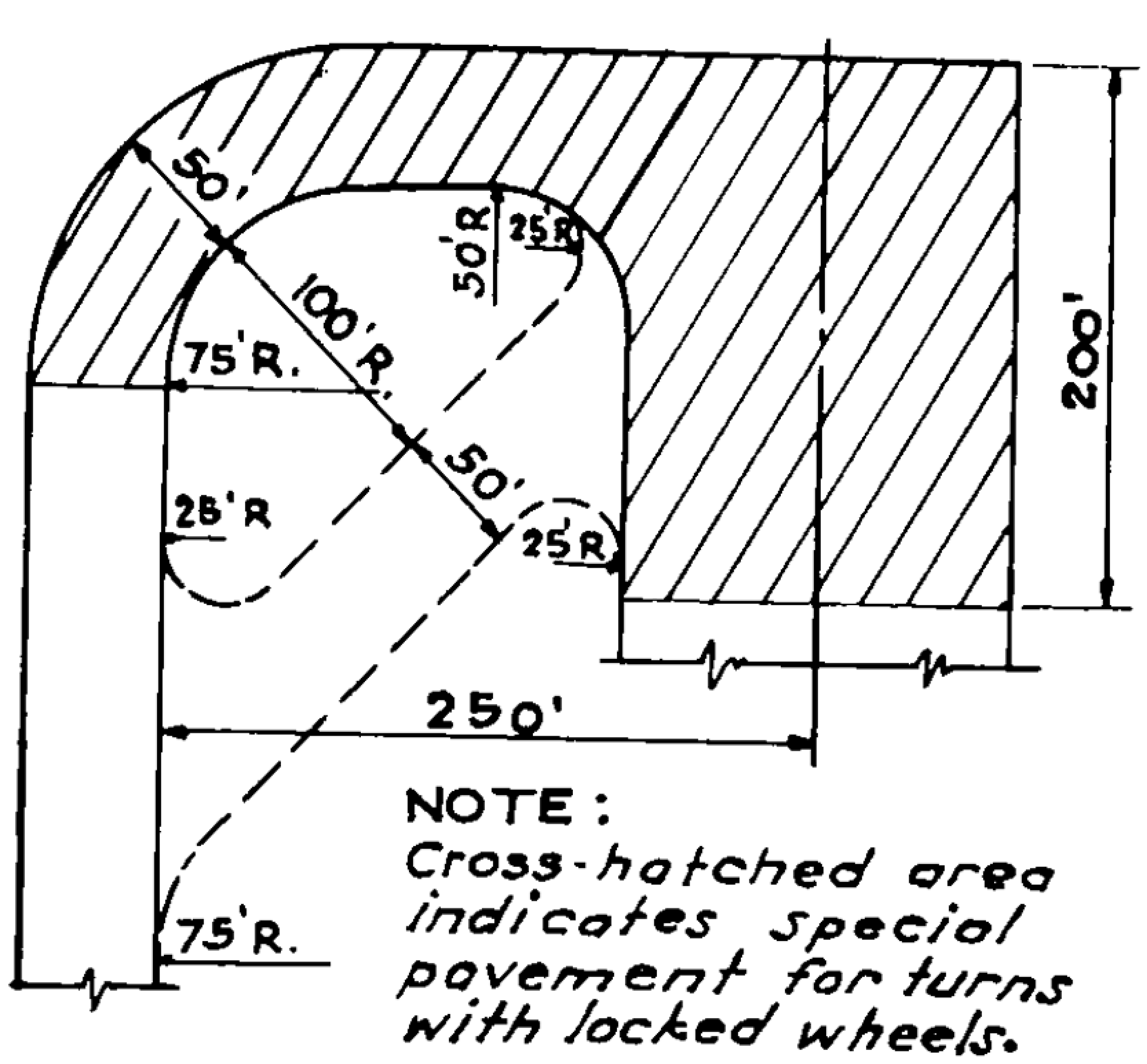


FIG. C - RUNWAY TURNAROUNDS.*

NOT REQUIRED AT RUNWAYS 150' & WIDER



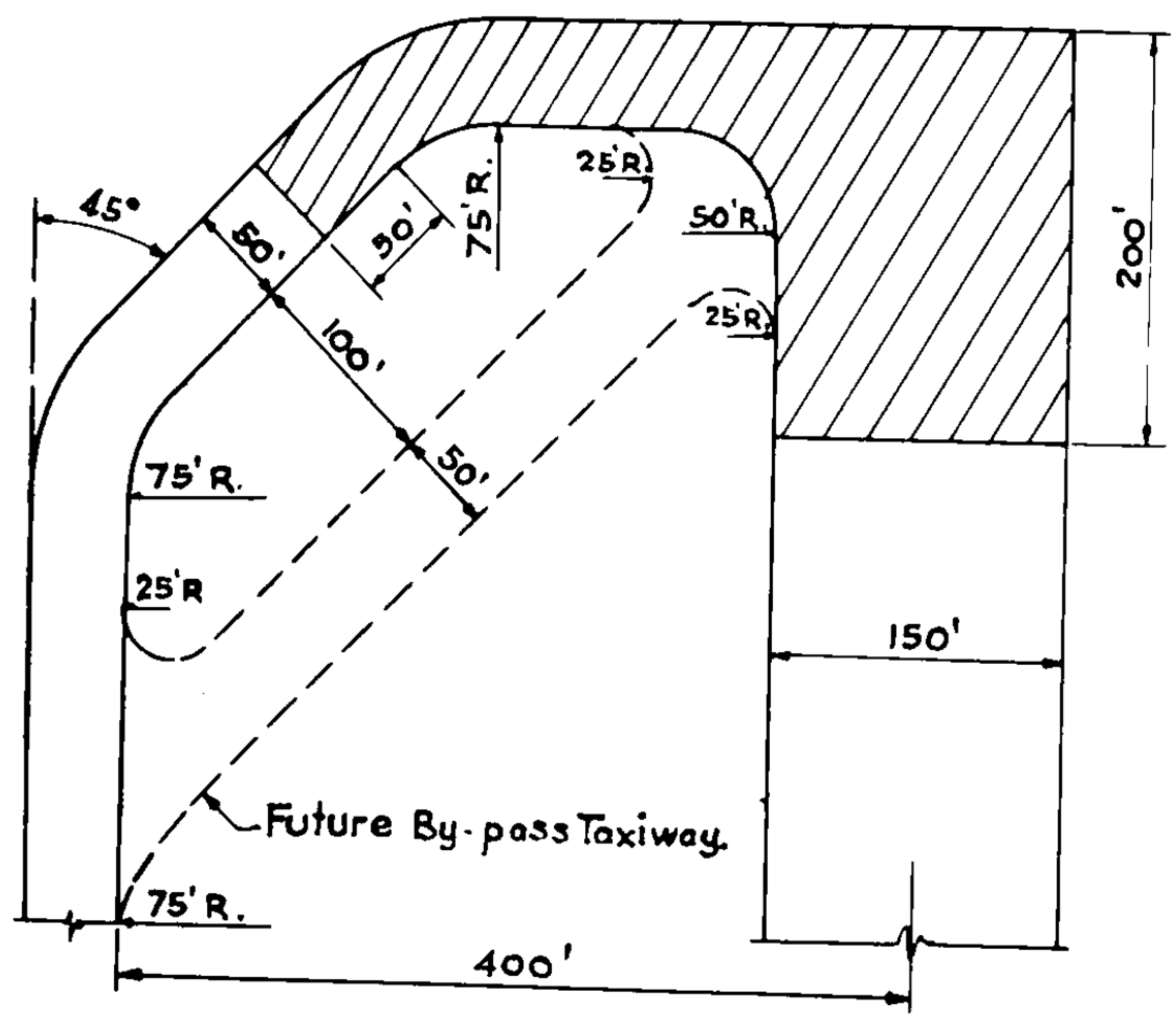


FIG. D - LAYOUTS OF ENDS OF RUNWAYS.*

* Adapted from C.A.A.

** From Engineering Manual - War Dept., Corps of Engineers, April 1943.

AIRPORTS - DRAINAGE - 1

GENERAL: Each site requires a special drainage solution. Amount of runoff, finished grades, topography, soil and ground water level are factors. Surface drainage systems. Figures A, B, C below, should always be provided to remove rainfall water remaining on the surface which would be a hazard to plane movements and would saturate the soil, causing possible frost damage and base instability; subdrainage systems may be required to lower the existing ground water level to such depth that base stability and frost protection will result; surface drainage system and sub-drainage system should never be combined.

DESIGN: See pg. 5-01, 02, 03 for general methods of computing runoff and below for C.A.A. recommendations.

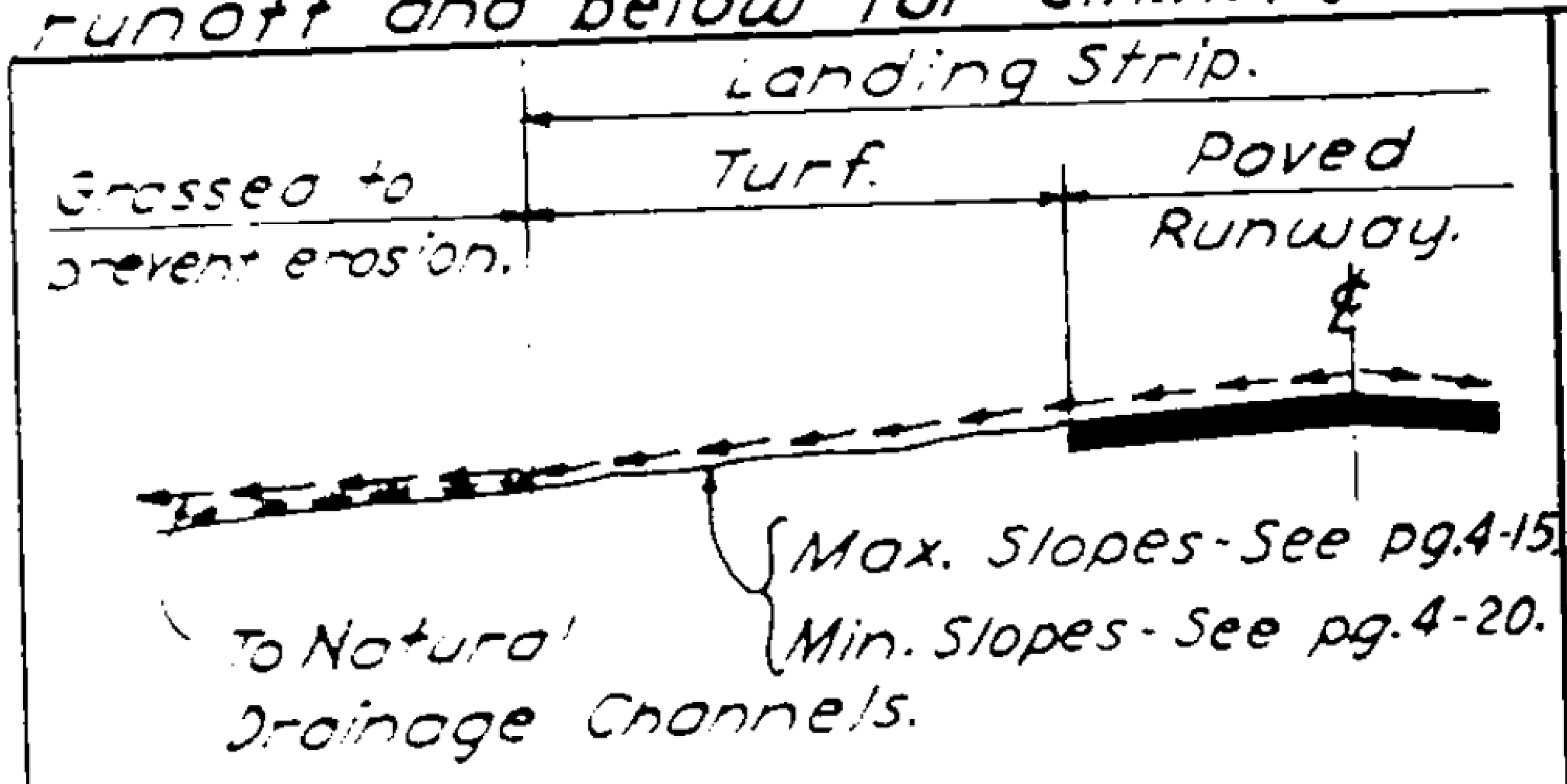


FIG. A - SURFACE DRAINAGE.

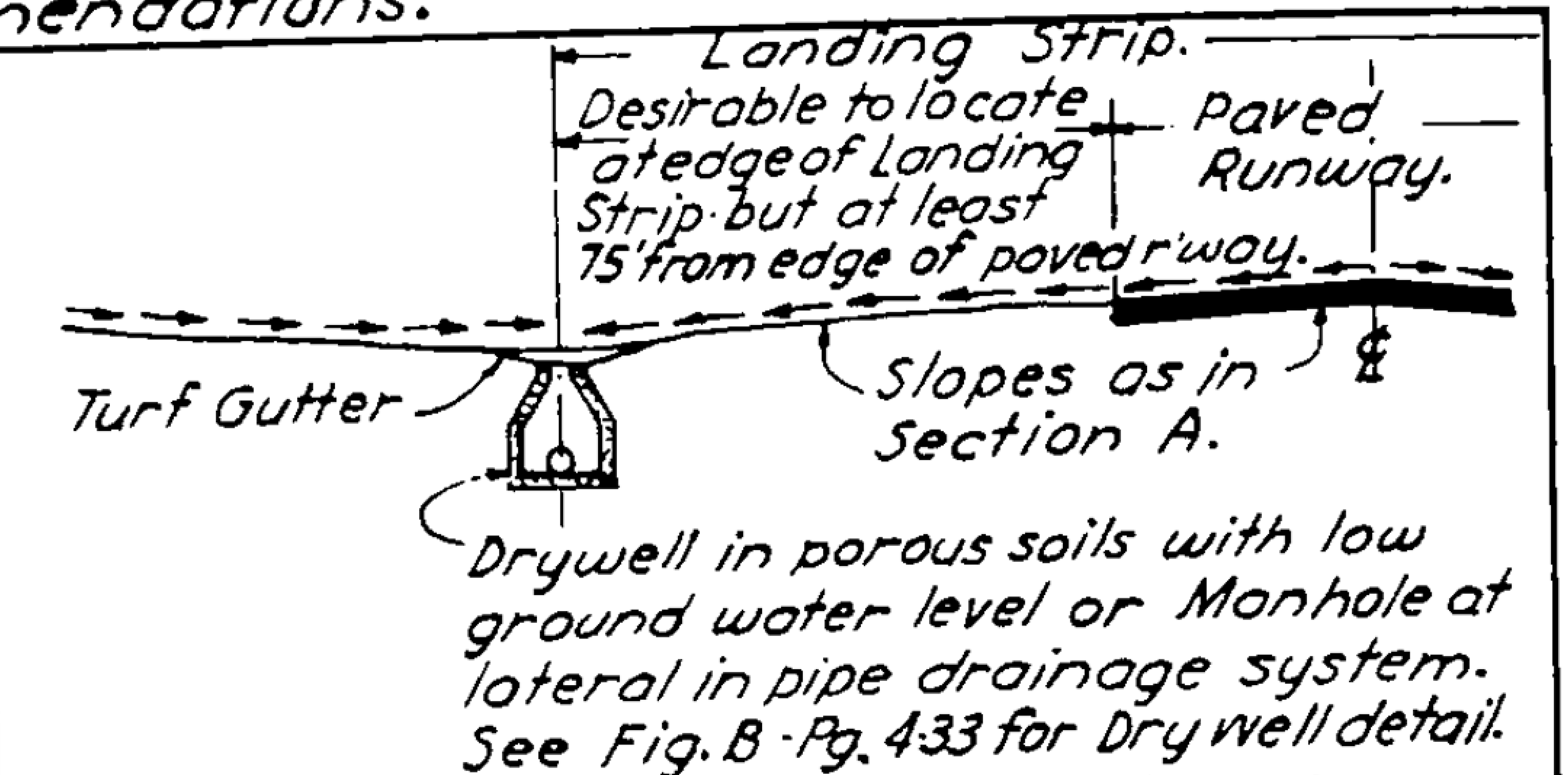


FIG. B - SURFACE DRAINAGE.

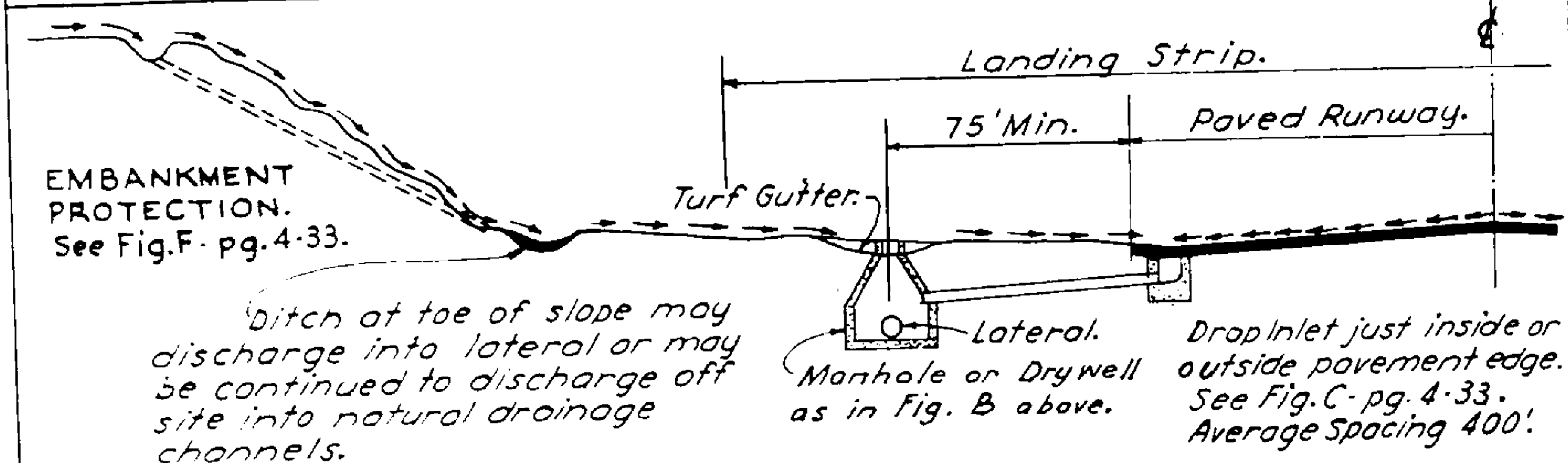


FIG. C - SURFACE DRAINAGE.

SURFACE RUNOFF COMPUTATIONS - C.A.A. METHOD - $Q = \frac{A \cdot I \cdot R}{T + t}$

Q = Runoff - Cu. ft. per Sec.
A = Drainage area in acres.
I = Percentage of imperviousness of the soil in Table at right.
R = Inches of rainfall per hour, use 2 yr. expectancy, Fig. A - pg. 5-00.
T = Duration of rainfall - Use 1 hour.
t = Time allowed for removal after storm - Use 2 hours (See note below).

VALUES OF I	
Runway Pavements	0.85 to 0.95
Heavy Impervious Soils No Turf.	0.50 to 0.80
Imp. Soils with Turf.	0.40 to 0.70
Pervious Soils - No Turf.	0.20 to 0.50
Pervious Soils - with Turf.	0.10 to 0.30

EXAMPLE: Given: Area = 6 acres, 1/3 paved ($I = 0.90$) and 2/3 turf on pervious soil ($I = 0.30$); Airport location - Central Ohio.

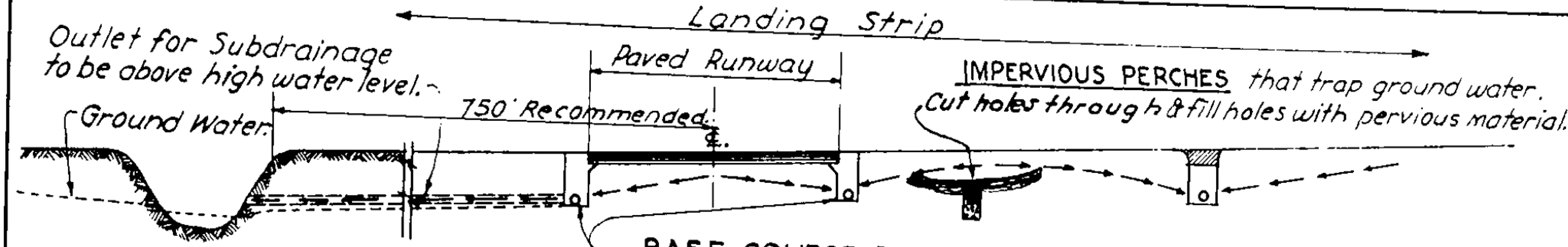
Required: Q.

Solution: Average $I = 1/3 \times 0.90 + 2/3 \times 0.30 = 0.50$

R from Fig. A - pg. 5-00 = 1.25 $\therefore \quad Q = \frac{6 \times 0.50 \times 1.25}{1 + 2} = 1.25$ Cu. ft. per Sec.

NOTE: Ponding during "t" time, 2 hrs., should be kept away from the edge of runways and traffic areas.

AIRPORTS - DRAINAGE - 2



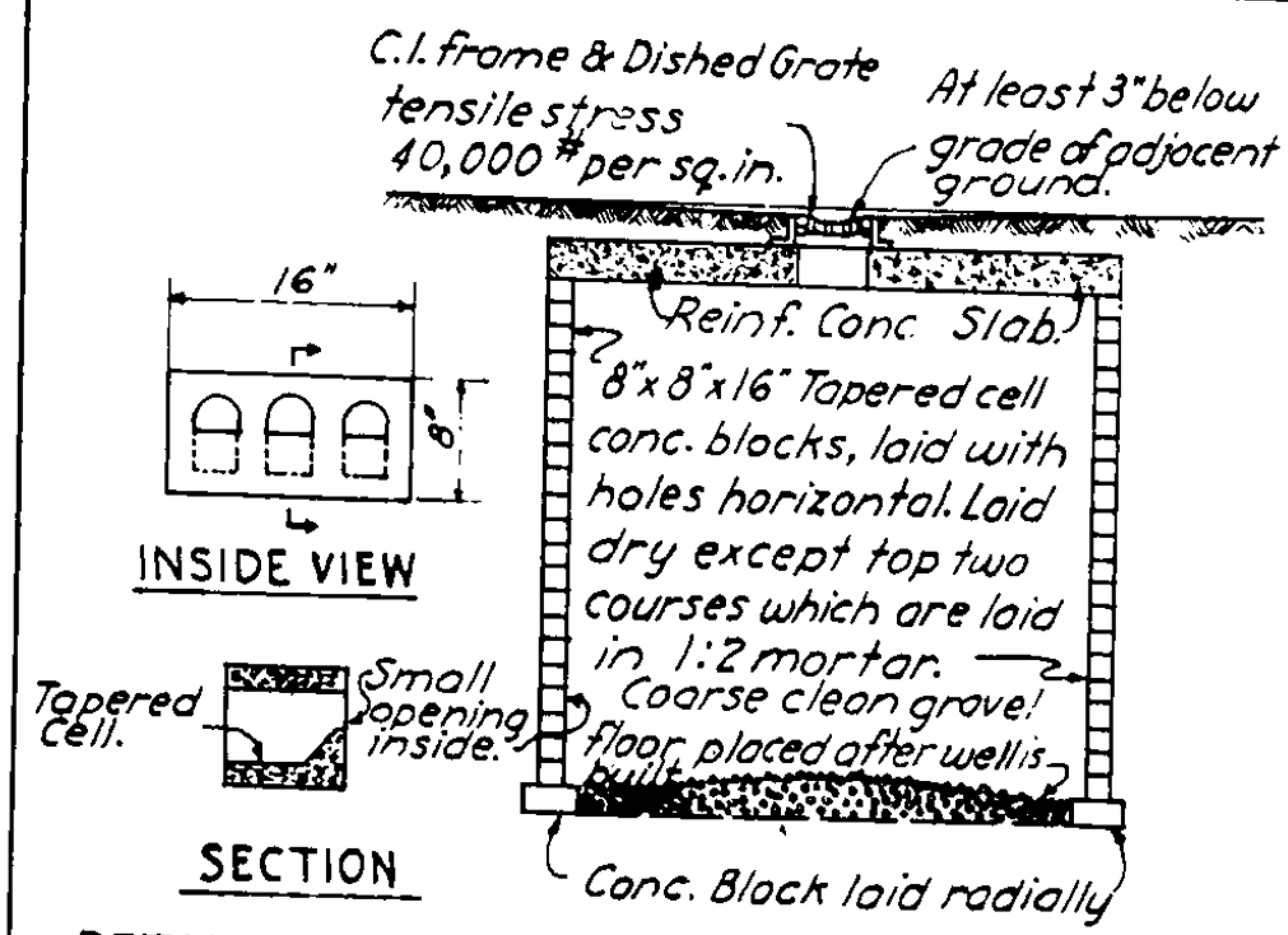
DEEP DRAINAGE DITCHES.
Located at airport boundaries to lower ground water. Both ditches & base course drains deep enough to lower ground water to required depth at center of runway.

BASE COURSE DRAINS (See below for detail). Not a substitute for surface drainage. Required to lower ground water to protect against frost action and saturated unstable bases. Additional drains under runway may be required.

SUBDRAIN CUTOFF.
Generally used to intercept ground water flow toward runway. Use detail similar to Fig. D below.

FIG. A - SUBDRAINAGE TO LOWER GROUND WATER.

See Pg. 5-06 & 5-07 for subdrainage design data.



DETAIL OF CONCRETE BLOCK FOR DRY WELLS.

SECTION THROUGH DRYWELL.

FIG. B - CIRCULAR DRY WELL.

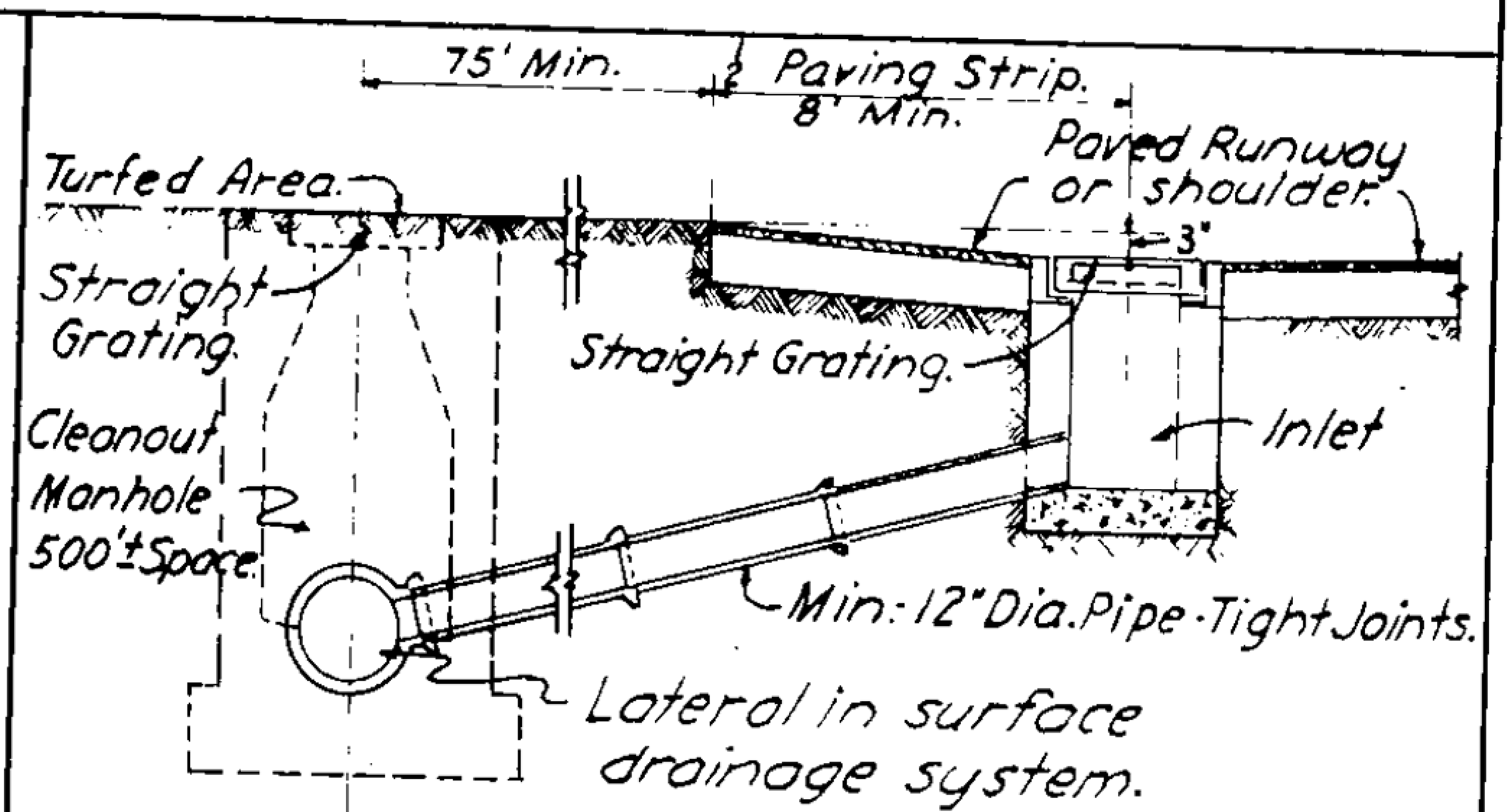


FIG. C - DROP INLET IN PAVEMENT.

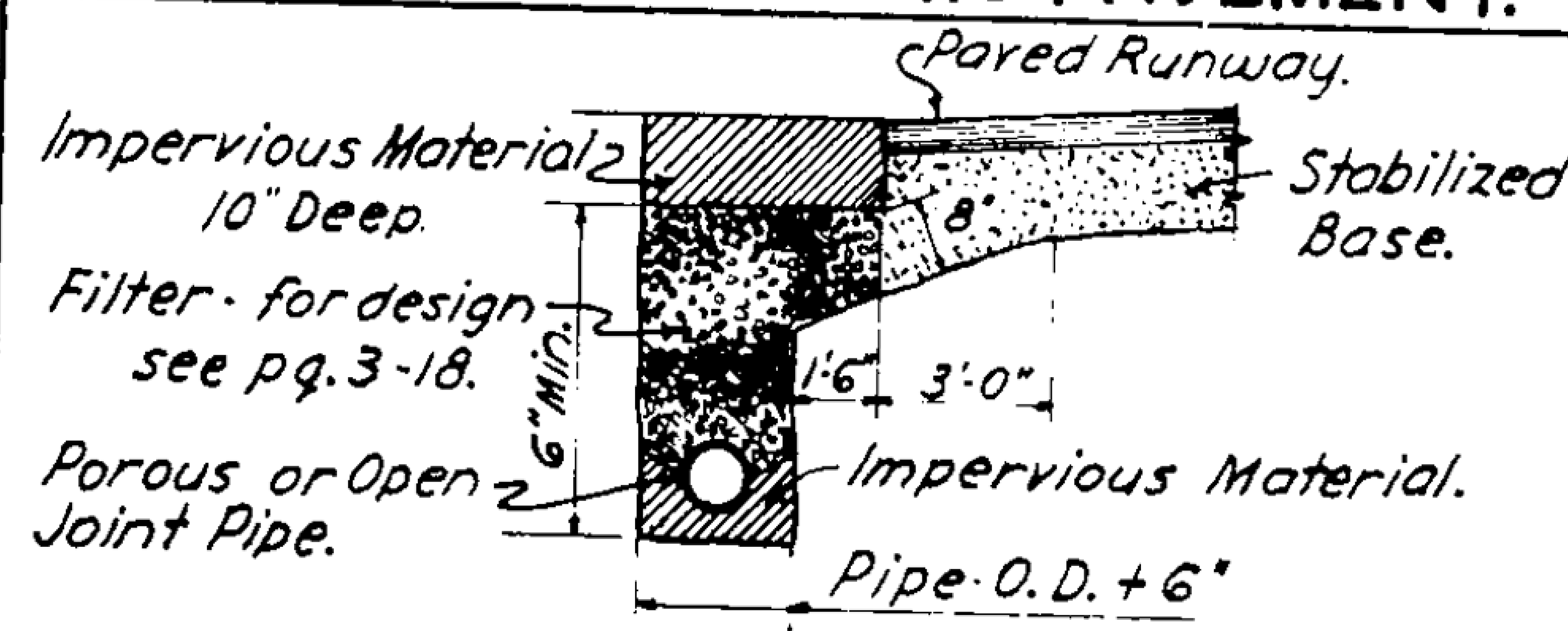


FIG. D - BASE DRAIN.*

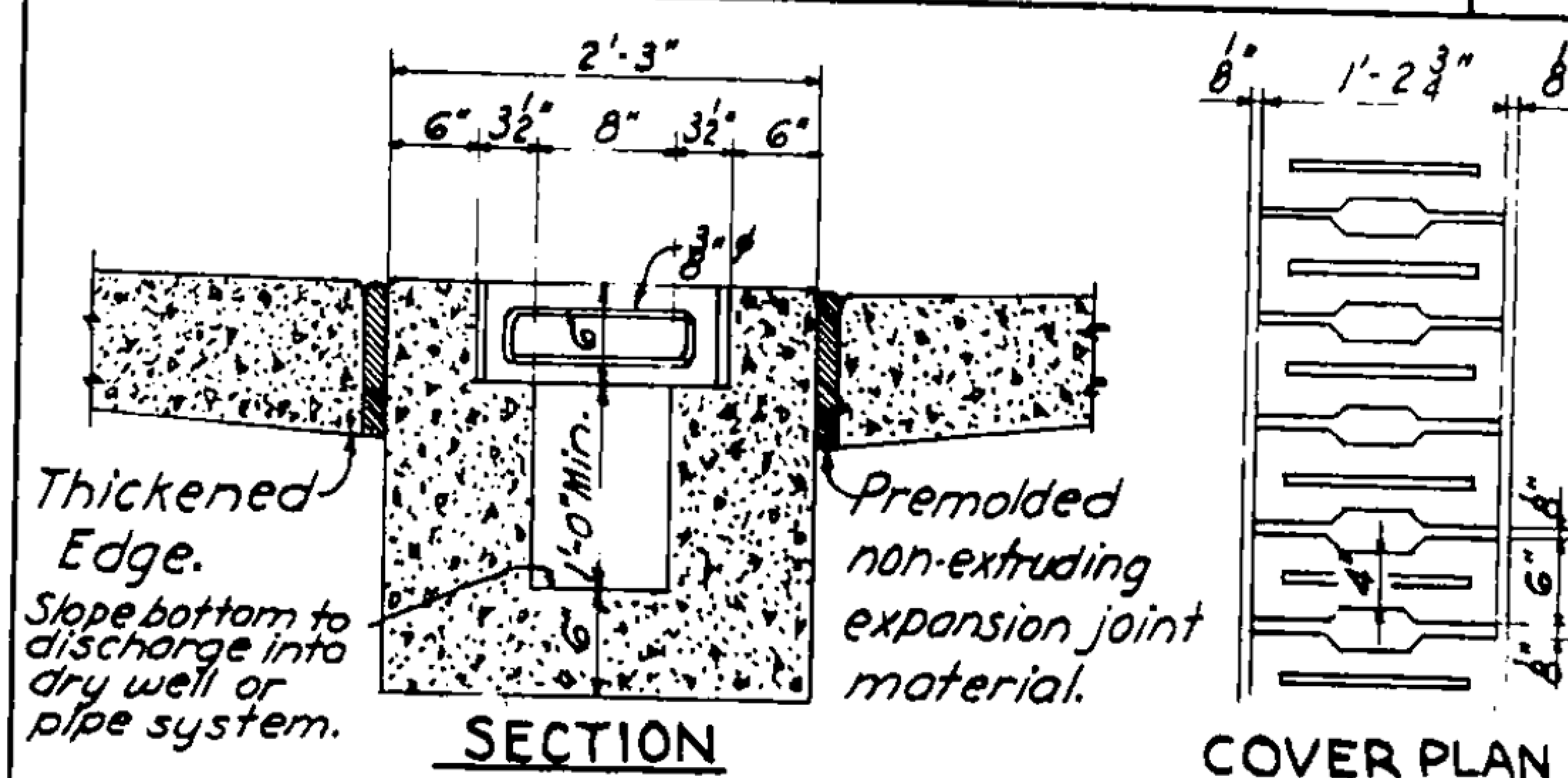


FIG. E - CLOSED GUTTER WITH PRECAST CONCRETE GRATE.

For use only where warping surfaces will not give sufficient slopes for runoff.

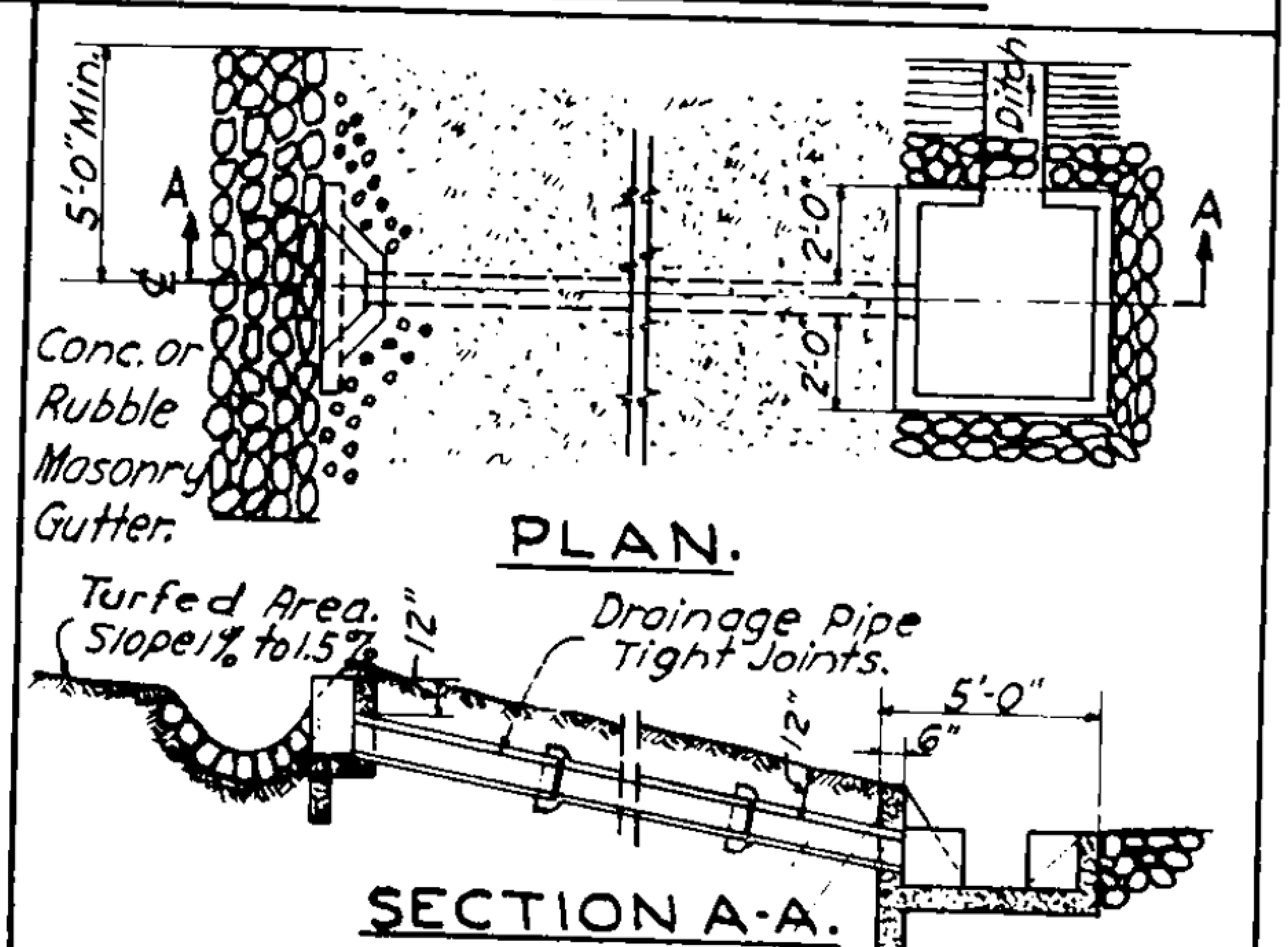
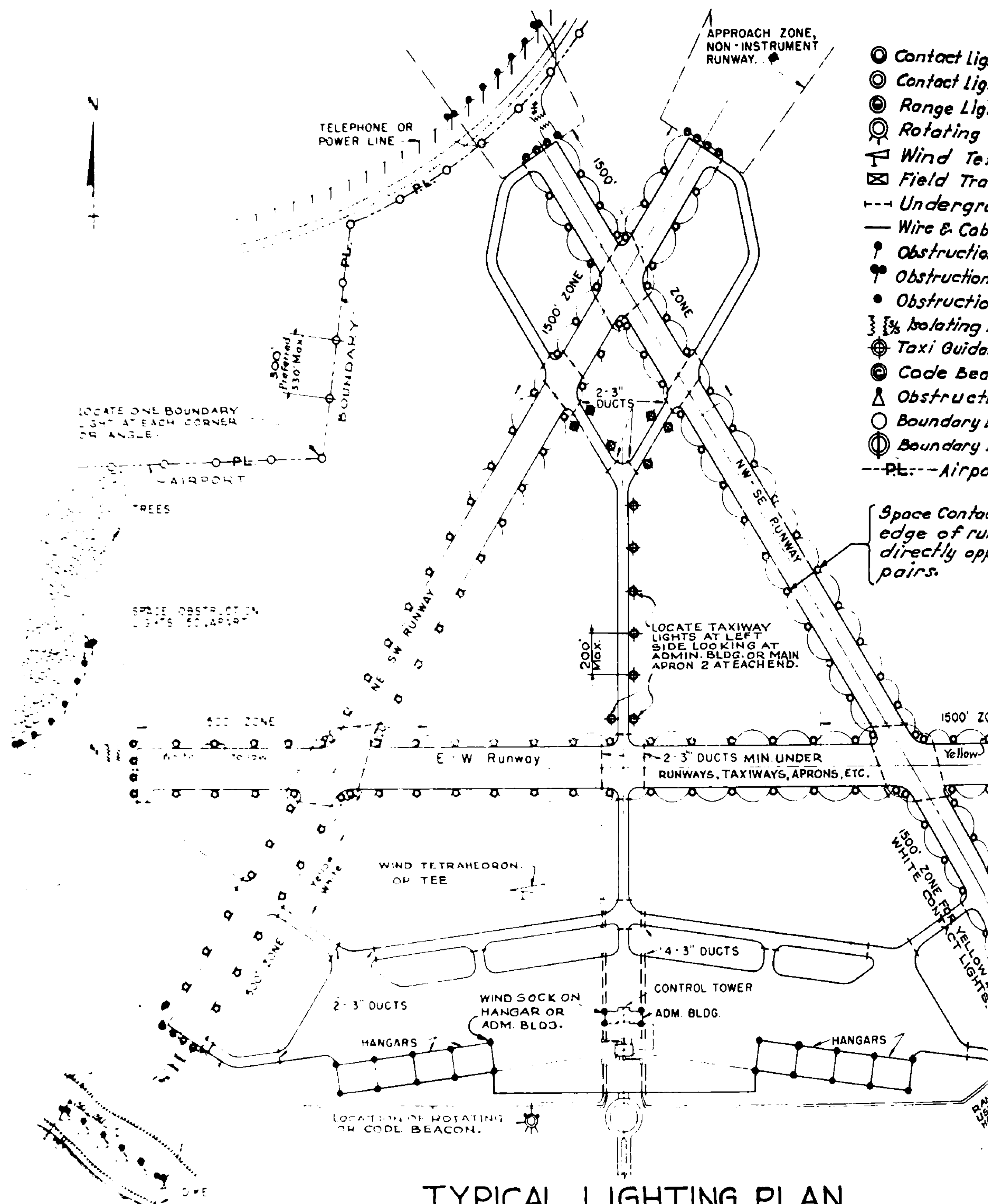


FIG. F - EMBANKMENT PROTECTION.*

*Adopted from C.A.A.

AIRPORTS



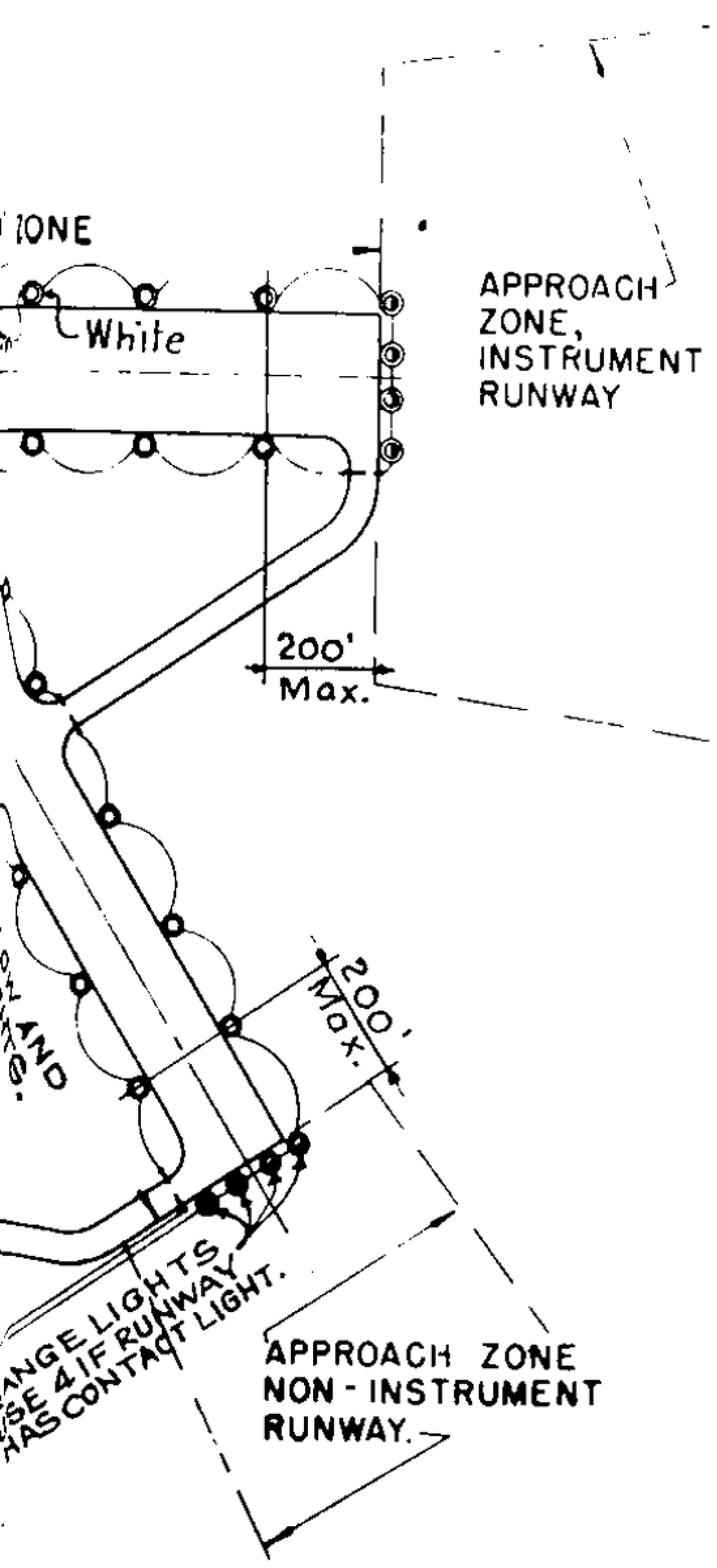
TYPICAL LIGHTING PLAN

LIGHTING *

LEGEND

...ct light, Flush Type 180° White-180° Yellow.
...ct light, Flush Type, White.
...e light, Flush Type, Green.
...ting Airport Beacon.
... Tetrahedron, Illuminated.
... Transformer Vault.
...erground Ducts (2-3").
...Cable Under Current Projects.
...uction Light, Single Unit, Red, on Pole.
...ction Light, Duplex Unit, Red, on Pole.
...ction Light, Single Unit, Red.
...ting Transformer, Series-To-Series.
...uidance Light-Flush Type, Blue.
...Beacon.
...uction Light, Cone Mounted, Red.
...ary Light, Cone Mounted, White.
...ary Light, Flush Type, White.
...irport Property Light.

...ntact Lights 200' ± apart at ...f runway as shown and ...opposite one another in



NOTES

GENERAL: For lighting requirements at different class airports, see Table B Page 4-18 except for airports used for emergency landings of large planes or as auxiliary or alternate terminal airports.

ROTATING BEACON: Required where airport more than 4 miles from airway or equivalent beacon. Locate close to landing area. (20' minimum above any nearby obstruction); get clear sweep to horizon. If more than 1-1/4 miles away from airport boundary, provide auxiliary green code beacon at airport. Beacons visible from control tower but no interference with operators' vision.

CODE BEACON: Locate as above to identify airport.

BOUNDARY LIGHTS: All lights to be visible to plane coming in at glide angle. If parallel to contact lights, space differently from contact lights to avoid confusion. All boundary lights to be clear cone mounted type except use clear flush type in instrument approach zone and in pavements.

RANGE LIGHTS: Space generally 50' o.c. at end of runway. Use cone mounted green where end of runway less than 300' from boundary. If boundary more than 300', use flush type green at end of runway and yellow cone lights in line of boundary lights. If no contact lights, code runways by greatest number of range lights at most used runway. Where high winds stir up snow and obscure surface lights, install floodlights at both ends of runway to act as range lights.

CONTACT AND TAXIWAY LIGHTS: Locate as shown on plan at left.

WIND TEE, TETRAHEDRON OR CONE: Locate visible from all directions. In general near location shown on plan at left.

ISOLATED OBSTRUCTIONS: Red always used for obstruction lights. Use disconnecting fittings for inspection if otherwise inaccessible. Wind cones, floodlights, beacon towers considered isolated.

LESS THAN 50' HIGH - one red light at top. More than 10' wide - one light at diagonal corners. For single tree --1 light 5' above top.

50 TO 200' - narrow tower, mast, flagpole, etc. - 1 duplex type (2 lamps burning or 2 lamps with automatic switchover if one goes out) at top and lights at third points or 50' points. 2 lights below top visible from any direction of approach.

200 TO 400' - provide code beacon with red filters and 2 - 500 watt lamps and flashing mechanism to produce 20 to 40 flashes per minute. At third points install additional lights as above - not more than 100' apart.

OVER 400' - consult C.A.A.

SMOKESTACKS, WATER TOWER, GAS HOLDERS, ETC. - 4 lights 90° apart at top and 4 at each 100' level with 2 visible from any direction.

EXTENDED OBSTRUCTIONS:

BUILDINGS, GRAIN ELEVATORS, GROUPS OF TREES, POLE LINES, ETC. - Locate lights to mark contour of obstruction from any approved direction, 150' spacing if close, 300' if distant from airport. All duplex units. Lights can be on obstruction or adjacent poles.

ADDITIONAL AIRPORT LIGHTING SYMBOLS.

- Hazard Beacon, Red, Rotating.
- Boundary light, Cone Mounted, 180° White-180° Yellow.
- Range Light, Cone Mounted, Green.
- Range light, Cone Mounted, Yellow, Auxiliary.
- Contact Light, Flush Type, Yellow.
- Contact Light, Snow equipped.
- Ceiling Projector.
- Wind Cone, Illuminated.
- Wind Tee, Illuminated.
- Neon Approach Light.
- Incandescent Approach Light.
- Floodlight, with Obstruction Lights.
- Field Transformer Vault, or Manhole.
- S/M Isolating Transformer, Series-To-Multiple.

* Adapted from C.A.A.

AIRPORTS - ADMINISTRATION BLDG. & FUELING

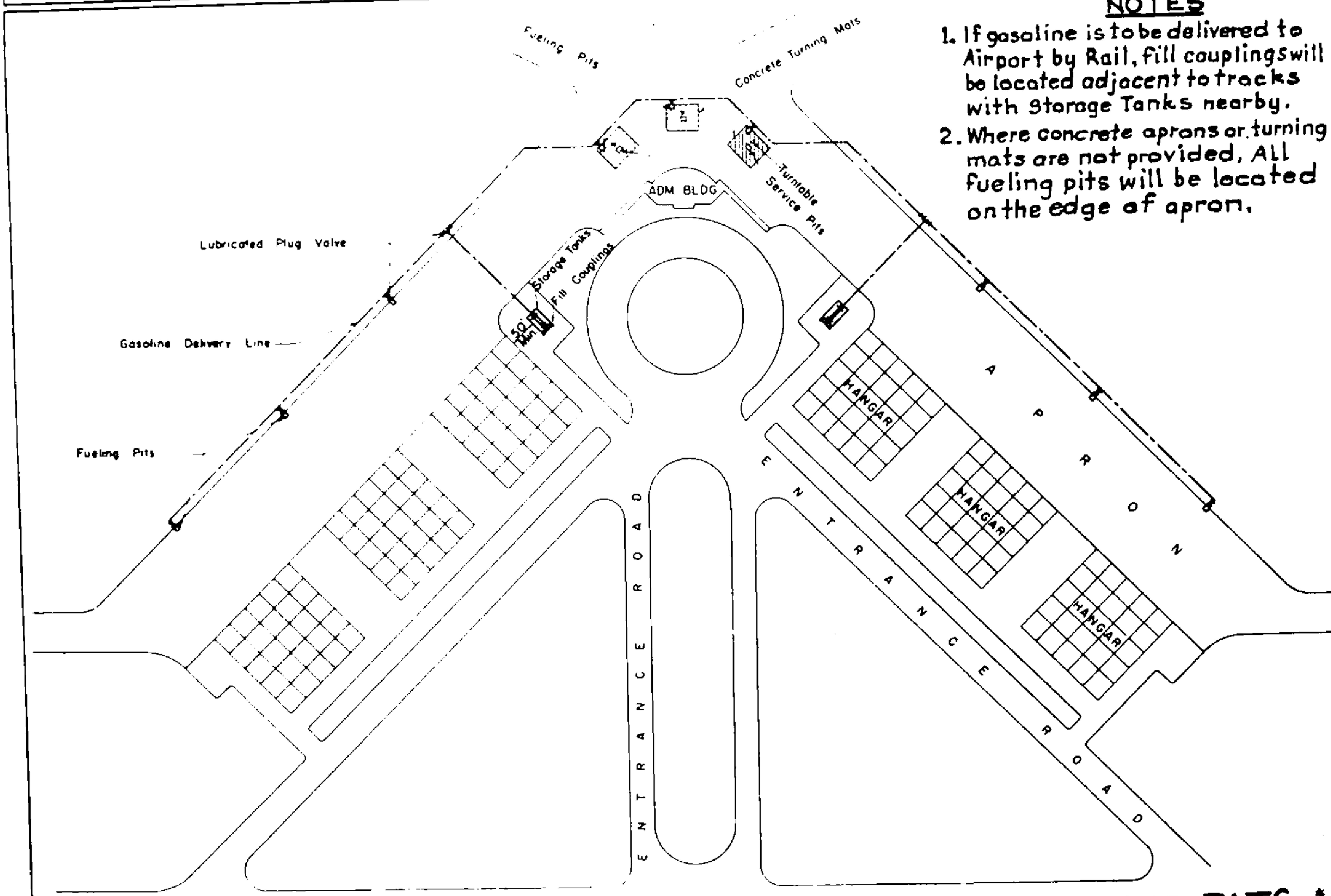
TABLE A - FLOOR AREAS IN ADMINISTRATION BUILDINGS BASED ON C.A.A. PLANS.

SPACE \ BLDG.	SMALL SIZE LOW COST	SMALL SIZE MEDIUM COST	MEDIUM SIZE	MAJOR SIZE
Waiting Room.	750□'	1400	4000	7500
Air corner space, including tickets, baggage, etc.	620□'	660	2800	5000
Operations.	425□'	180	600	1000
Office space.	180□'	800	1100	9000
Storage.	40□'	1100	1600	3300
Toilet.	350□'	450	1700	2400
Post Office & Air Express, including landing platform.	Mail Box	300	1400	3500
Concessions.	125□'	250	300	300
Telephone Booths.	2	4	12	18

SPACE \ BLDG.	SMALL SIZE LOW COST	SMALL SIZE MEDIUM COST	MEDIUM SIZE	MAJOR SIZE
Restaurant facilities.		900	2100	6000
Weather Bureau.		165	800-1400	800-1400
Airways Communications.		165	1000-1500	1000-1500
Work Shop.		360	1500	2000
Locker Room, Showers & Toilets.		250	1200	1800
Heating, Mechanical Equipment, etc.		440	800	2100
Pilots' Chart Room			425	425
Airway Traffic Control Room.			1000 Min.	1000 Min.
Control Tower.			120	250
Theodolite Dome.			150	150

NOTES

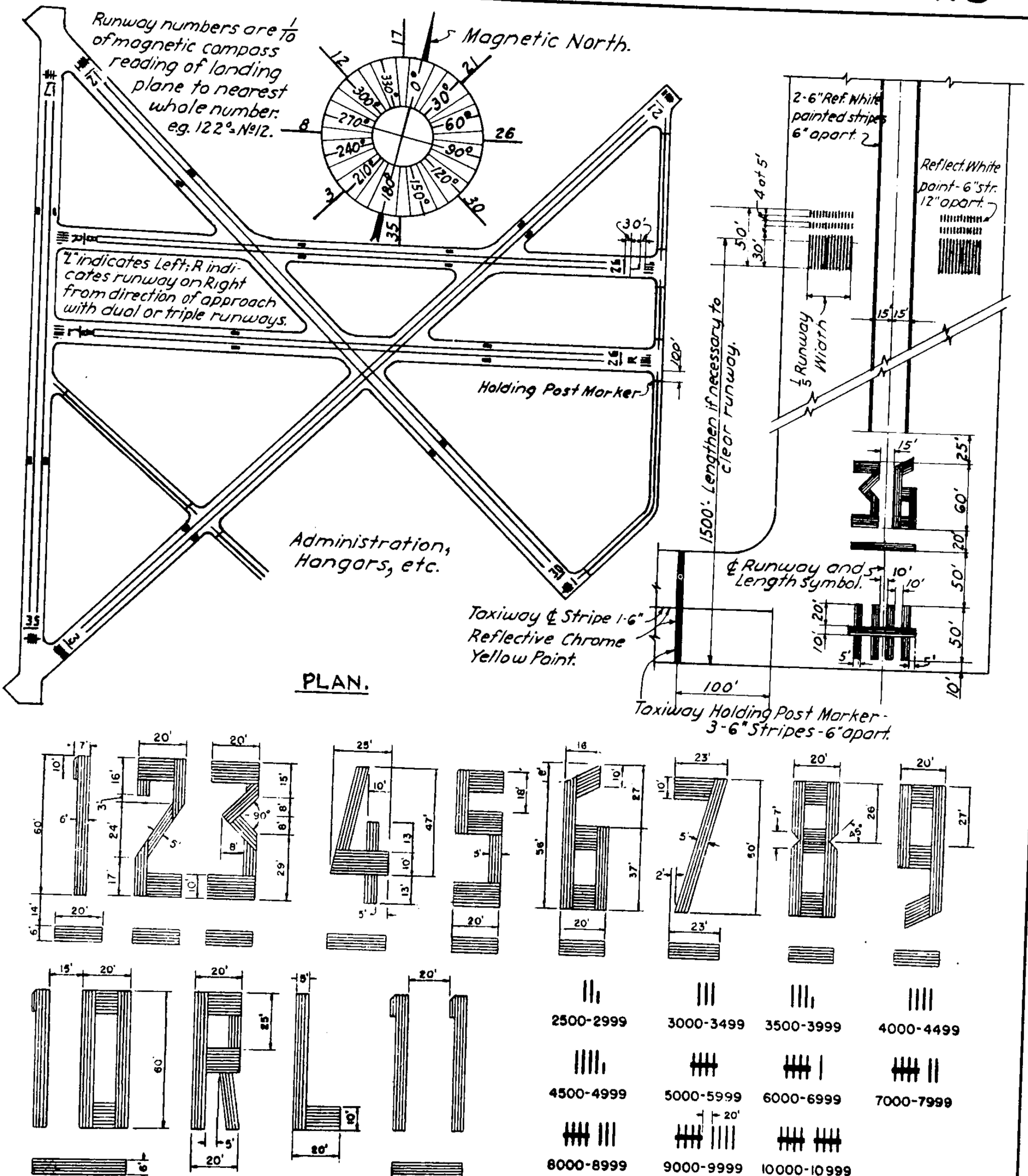
1. If gasoline is to be delivered to Airport by Rail, fill couplings will be located adjacent to tracks with Storage Tanks nearby.
2. Where concrete aprons or turning mats are not provided, ALL fueling pits will be located on the edge of apron.



LOCATION OF GASOLINE STORAGE TANKS AND FUELING PITS. *

* From C.A.A.

AIRPORTS - NUMBERING & MARKING RUNWAYS*



RUNWAY NUMBERS AND LENGTH SYMBOLS.

Use a non-reflective white or black paint.
Paint solid or 6" stripes 2' apart.

*Adapted from Dwg - ANC - 1100 of C.A.A.

BRIDGES - LIVE LOADS* - 1

RAIL ROADS (STEAM OR ROAD ENGINE).

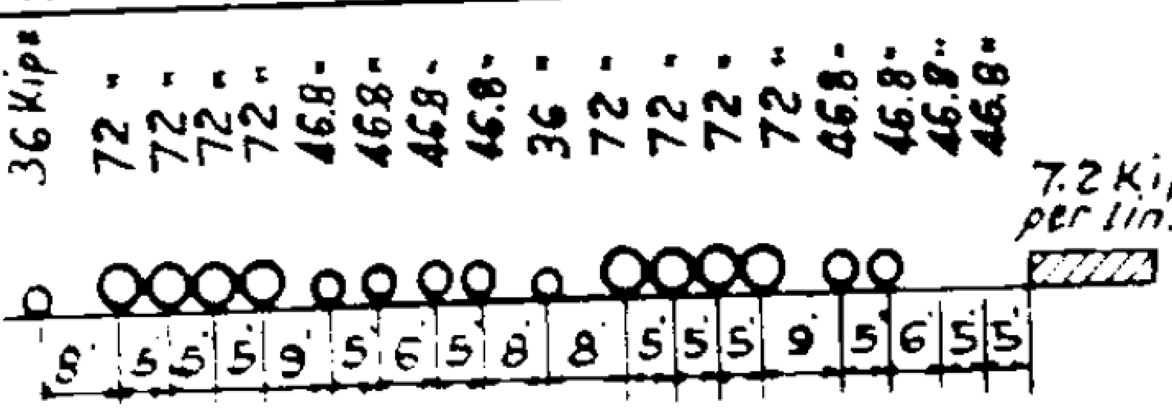
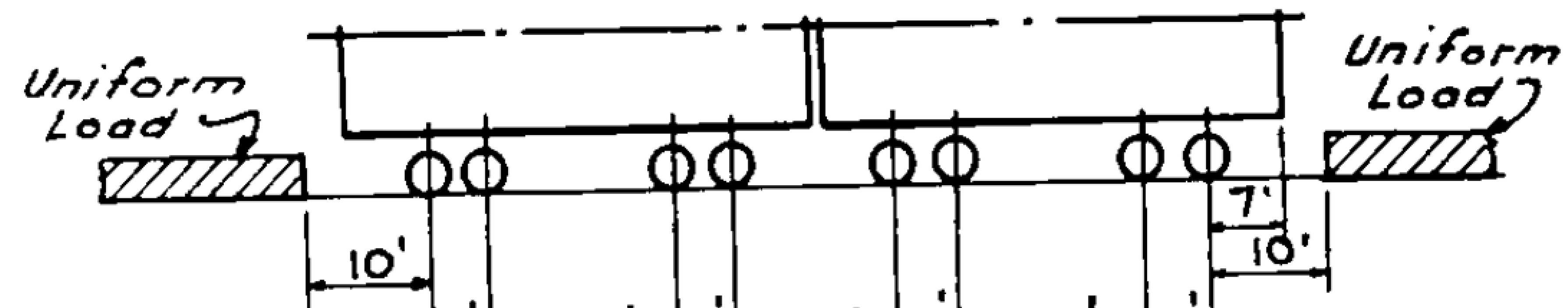


FIG. A - **COOPER E-72**

FIG. B

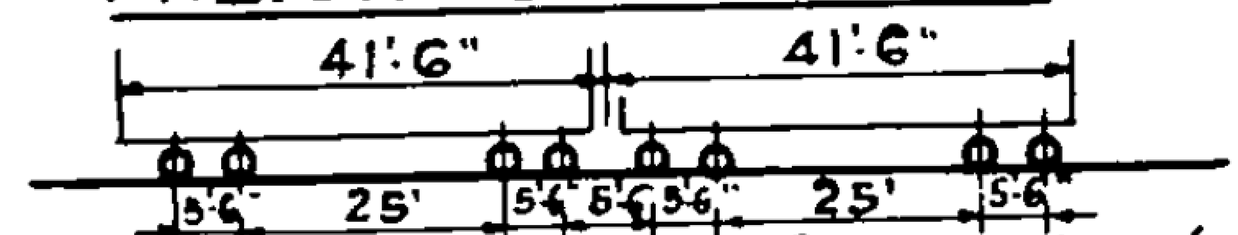
Recommended live load for each track-use Fig. A or B loading, whichever gives larger stresses. For other classes of loading the live load is: load in diagram × $\frac{class}{72}$
(Axle spacing shall remain the same).
For members receiving load from more than one track the proportions of full live load on the tracks are: for 2 tracks - 100% of live load.
" 3 " - 100% of L.L. on 2 tracks + 50% of 3rd.
" 4 " - 100% of L.L. on 2 tracks + 50% of 3rd + 25% L.L. on 4th.
Select tracks to give the greatest live load stress.

ELECTRIC RAILWAYS (TROLLEYS).



60 TON CARS	7'	30'	7'	14'	7'	30'	7'
50 " "	7'	25'	7'	14'	7'	25'	7'
40 " "	6'	20'	6'	14'	6'	20'	6'
30 " "	6'	18'	6'	14'	6'	18'	6'
20 " "	5'	16'	5'	14'	5'	16'	5'

FREIGHT CAR LOADING



Total loaded weight of Car + 10% overload.
40 Ton capacity = 132,000 lbs.
70 " " = 212,000 lbs.

HIGHWAYS

H20-S16 - *Express Highways with Commercial Traffic, Thruways, Heavy duty. Commercial streets. All structures on Interregional Highway System.*
H20 - *Parkways, and similar to above in many states.*
H15-S12 & H15 - *Used by many states for highways listed above.*
H10 - *Light traffic only.*

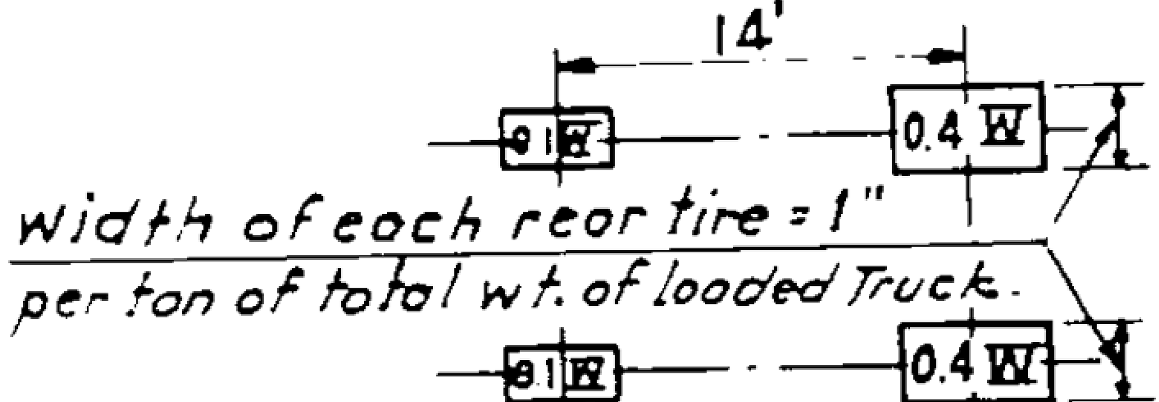
H-LOADING | **H-S-LOADING**

W = total weight of loaded truck.

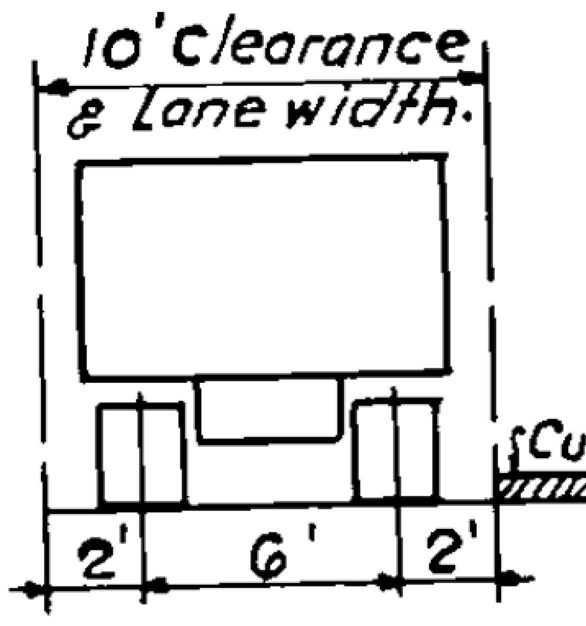
Use Loading, truck or lane, that produces maximum stress.

Under 40' span, use truck loading. 40' span and over use lane loading.

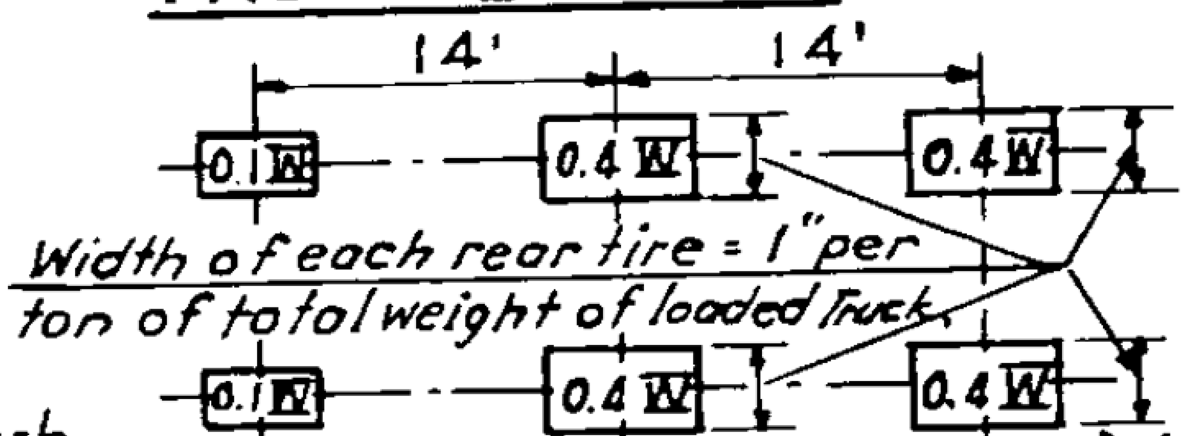
TRUCK LOADING (H)



Axle Loads:
- H 20 - 8 Kips | 32 Kips
- H 15 - 6 " | 24 "
- H 10 - 4 " | 16 "



TRUCK LOADING (H-S)



Axle Loads:
- H20-S16 - 8 Kips | 32 Kips | 32 Kips
- H15-S12 - 6 " | 24 " | 24 "

LANE LOADING (H)

H 20: Concentrated load {18,000 for Moment. 26,000 for Shear. Uniform load 640 lbs. per Lin. Ft. of Lane

H 15: Concentrated Load {13,500 for Moment. 19,500 for Shear. Uniform load 480 lbs. per lin. ft. per lane

H 10: Concentrated load {9,000 for Moment. 13,000 for Shear. Uniform Load 320 lbs. per Lin. ft. of Lane

LANE LOADING (H-S)

H 20 - S 16: Concentrated Load {32,000 for Moment. 40,000 for Shear. unif. Load 640 lbs. per lin. ft. of lane.

H 15 - S 12: Concentrated Load {24,000 for Moment. 30,000 for Shear. Uniform Load 480 lbs. per Lin. ft. of lane.

1. *Number after H means gross truck weight in tons.*
2. *Numbers after H 20 - S16 mean; a 20 ton tractor + trailer with a 16 ton rear axle load.*

REDUCTION IN LOAD INTENSITY.

Where maximum stresses are produced by loading any number of lanes simultaneously, use following percentages of resultant live load stresses:

1 or 2 lanes	100%	Suggested by S. Hardesty:	
3 Lanes	90%	4 Lanes	85%
4 or more lanes	75%	5 or more lanes	75%

* *Loads adapted from A.R.E.A. or A.A.S.H.O. Specs.*

BRIDGES - LIVE LOADS - 2

HIGHWAYS †

OVERLOAD:
Check design, except flooring, with truck loading increased 100% in one lane only. Resulting stresses must be less than 150% of design stresses.

IMPACT:
Increase Stress by $S' = S \cdot \frac{50}{L+125}$
L = Span length* of member in ft.
S = Stress without impact.
S+S' = Stress with impact.

Maximum Stress increase due to impact.

Highway & Culverts < 1ft. cover	30%
Culverts < 2ft. cover	20%
Culverts < 3ft. cover	10%

Where applied.

Superstructure including: Columns, Towers, Rigid frames above ground surface.

Where not applied.

Foundation pressure. Timber structures. Sidewalk loadings. Substructures. Culverts > 3' cover.

LONGITUDINAL FORCES:
5% of lane load with concentrated load for Moment applied 4' above roadway + longitudinal force due to friction at expansion bearings.

LATERAL FORCES:
WIND: - 30# per sq. ft.
(a) Wind application on structures - 30# per sq. ft. on projected area of one truss + 15# per sq. ft. on projected area of each additional truss.
**Wind application on moving load Highways - 200# per lin. ft. ; Highway with trolleys - 300# per lin. ft. } applied 6'0" above floors.
(b) Total wind force not less than: 300# per lin. ft. - Loaded Chord*** ; 150# per lin. ft. - Unloaded Chord } Truss Span. 300# per lin. ft. - Girder Span.
(c) Total Wind Force on unloaded structure - not less than 50# per sq. ft. on projected area of one truss + 25# per sq. ft. on projected area of each additional truss.

UPLIFT:
Check uplift on bents by applying 400 lbs. per lin. ft. on the lee side for highway bridges and 800 lbs. per lin. ft. for highway bridges with trolleys.

CENTRIFUGAL FORCE:
From trolleys on curved track - apply 10% trolley live load as lateral force 4' above rail.

SIDEWALK & SAFETY CURB OVER 2' WIDTH:
Slabs, stringers and immediate supports - 85 lbs. per sq. ft.
Girders, trusses, arches, etc. - 26' to 100' = 60 lbs. per sq. ft.
" " " " over 100' = $(30+\frac{3000}{L})(\frac{55-W}{50})$ lbs. per sq. ft.
Where L = Loaded length of sidewalk in ft. W = Width of sidewalk in ft.

THERMAL FORCES:
Metal for moderate climate - 0° F. to +120° F; cold climate - -30°F to +120°F.
Concrete " " " - Rise 30°F; fall 40°F " " Rise 35°F; fall 45°F.

PRESSURE ON PIERS - ICE: 400 lbs. per sq. ft. Thickness and height dependent on local conditions (50 kips per sq. ft. on width of pier commonly used). FLOWING WATER: KV^2 lbs. per sq. ft. where V = velocity in ft. per sec. & K = 1⅓ for sq. ends, ⅔ for circ. & ½ for angle ends < 30°.

EARTH PRESSURE:
See pg. 2-69. No structure to be designed with less than 30 lbs. per cu. ft. fluid pressure. Provide surcharge when highway traffic can come within a distance from the top of the structure equal to one-half its height; the pressure of 30 lbs. per cu. ft. shall have added to it a live load surcharge pressure equal to not less than 2 feet of earth or use fluid pressure of 60 lbs. per cubic foot.
No live load surcharge if approaches are framed.

SNOW & ICE LOADS: No allowance to be made.

RAILINGS AND CURBS: See Pg. 4-55.

*For negative moment use span where greatest load is applied.
**A floor system may be used on horizontal girder to resist wind if it is adequately designed and adequately anchored.
***Chord into which floor beams frame.
† Adapted from A.A.S.H.O. Specs. for Bridges.

BRIDGES - LIVE LOADS - 3

RAILROADS*

FOR SIDINGS & ROADS WHERE LOW SPEEDS ONLY WILL BE USED:** Use impact 50% and omit all other rules except the laws of mechanics.

IMPACT: Increase stress as follows:
(a) Rolling effect of axle load acting downward on one rail and upward on the other. $S_1 = 10\%$ $S+$ on one rail, $-$ on the other.
(b) Direct vertical effect: For Steam Locomotives.
Where L = less than 100' $= (100 - 0.60L) \times$ axle load $\div 100$.
" L = 100' or more $= \left(\frac{1800}{L-40} + 10\right) \times$ axle load $\div 100$.

For Electric Locomotives $= \left(\frac{360}{L} + 12.5\right) \times$ axle load $\div 100$.

L = Length, in feet, center to center of supports, for stringers, longitudinal girders or trusses, or = length, in feet, of transverse floor beams or girders, for floor beams, floor beam hangars, sub diagonals of trusses, transverse girders and their supports.
Members receiving load from > one track:
Two Tracks.
L = Less than 175' = Full impact of two tracks.
L = 175' to 225' = Full impact of one track + $(450 - 2L)\%$ of other.
L = Over 225' = Full impact of one track + none of other.
> Two Tracks - Full impact of two tracks.

LONGITUDINAL FORCES: Add to live load on one track only at 6' above rail.
15% of live load without impact for braking or
25% load on driving wheels without impact - for traction, whichever is larger.
Decrease 50% where abutments will take part of load.

LATERAL FORCES:
WIND PRESSURE: In any horizontal direction.
(a) Wind application on moving load - 300 lbs. per l.f. of one track at 8' above rail.
Wind application on structure - 30 lbs. per sq. ft. as follows: girder spans - $1\frac{1}{2}$ x vertical projection of span; truss spans - vertical projection of span + any portion of leeward trusses not shielded by floor system; viaduct towers and bents - vertical projection of all columns and tower bracing.
(b) Total wind force on girder & truss spans: not less than 200 lbs. per l.f. on loaded flange or chord (flange or chord supporting floor beams) + 150 lbs. per l.f. on unloaded flange or chord.
(c) Total wind force on unloaded bridge - not less than 50 lbs. per sq. ft. on surfaces as in (a) above.
NOSING OF LOCOMOTIVES: A lateral force to be added.
20,000 lbs. at top of rail at any point in either lateral direction (vertical effects of this force to be disregarded).
CENTRIFUGAL FORCE on curves: Apply horizontally 6' above ℄ of track at each axle.
Percentage of axle load to apply $= 1.755(E+3)$, where E = Superelevation in inches.

STABILITY OF SPANS & TOWERS: Use a live load of 1,200 lbs. per l.f. on one track without impact - on multiple track bridges place this live load on leeward side.

BRACING BETWEEN COMPRESSION MEMBERS: Design for transverse shear in any panel equal to ½% of total axial stress in both members in that panel + shear from lateral forces.

REVERSAL OF STRESS: Design members subject to reversal of stresses for each stress + 50% of smaller stress. Connections to be designed for sum of max. stresses.

COMBINED STRESSES: Members subject to both axial & bending stresses, including bending due to floor beam deflection, shall be designed so that combined fiber stresses will not exceed allowable axial stress. In members continuous over panel points add ¾ of bending stress, computed as for simple beams subject to axial stress. Members subject to a combination of dead, live, impact loads and centrifugal force with other lateral forces and with longitudinal forces or bending due to such forces allow 25% increase in unit stresses; any member shall resist stresses due to dead, live, impact loads + centrifugal forces without increase in allowable stresses.

SECONDARY STRESSES: If exceeding 4,000 lbs. per sq. inch in tension or 3,000 lbs. per sq. inch in compression to be treated as primary forces. Secondary stresses due to truss distortion usually need not be considered in any member the width of which, measured parallel to the plane of distortion, is less than 1/10th of its length.

*Adapted from A.R.E.A. specifications. ** By author.

BRIDGES – LIVE LOAD DISTRIBUTION* – 1

NOTATION

E = Width of slab in feet over which wheel load is distributed.

P = Load on one wheel.

P' = Concentrated lane load per lane.

N = Maximum number of lanes of traffic.

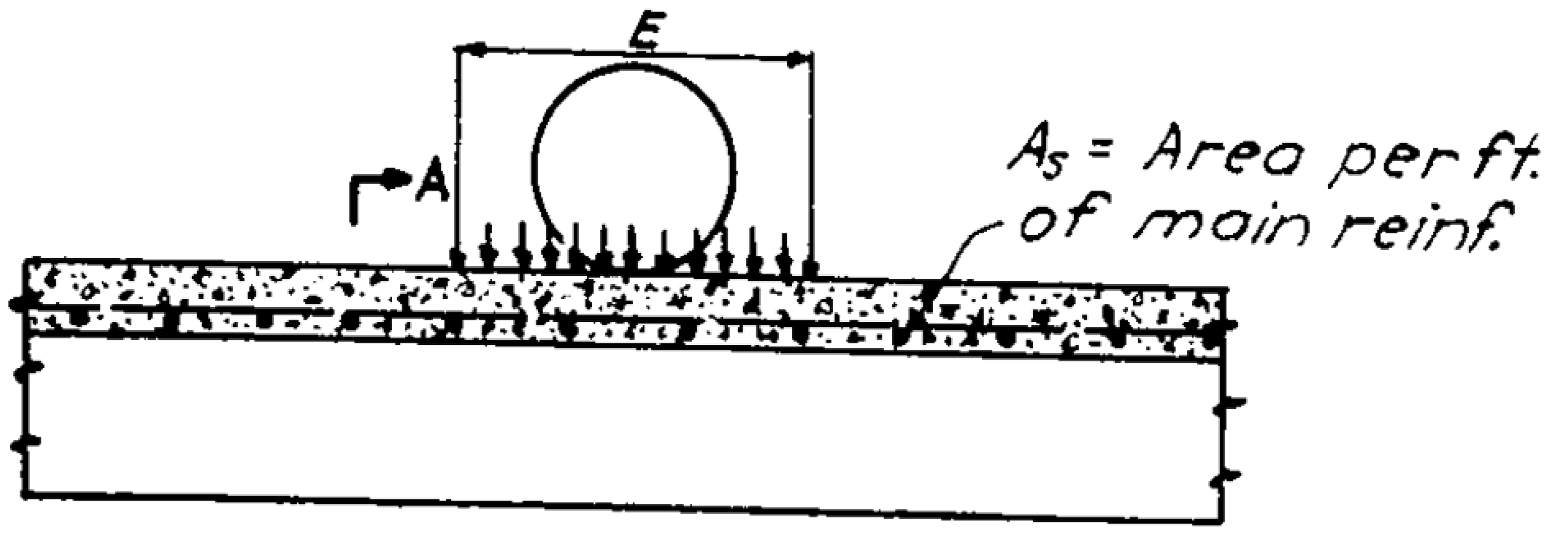
W = Width of roadway - curb to curb.

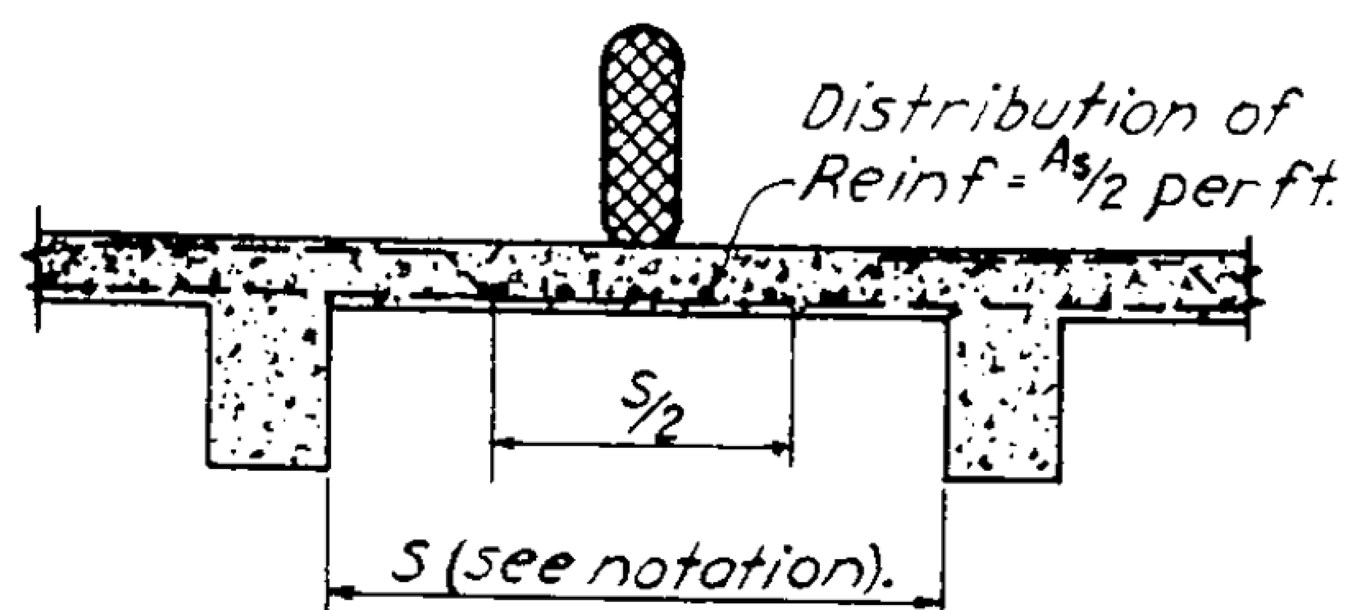
Q = Uniform lane load per linear ft. of lane.

S = Effective span length in feet.

FOR SIMPLE SPANS: C to C of supports, but not over clear span + slab thickness.

FOR CONTINUOUS SPANS - MONOLITHIC: Use clear span. OVER STRINGERS OR FLOOR BEAMS: Use clear span + ½ flange width (steel) or ½ beam width (timber).



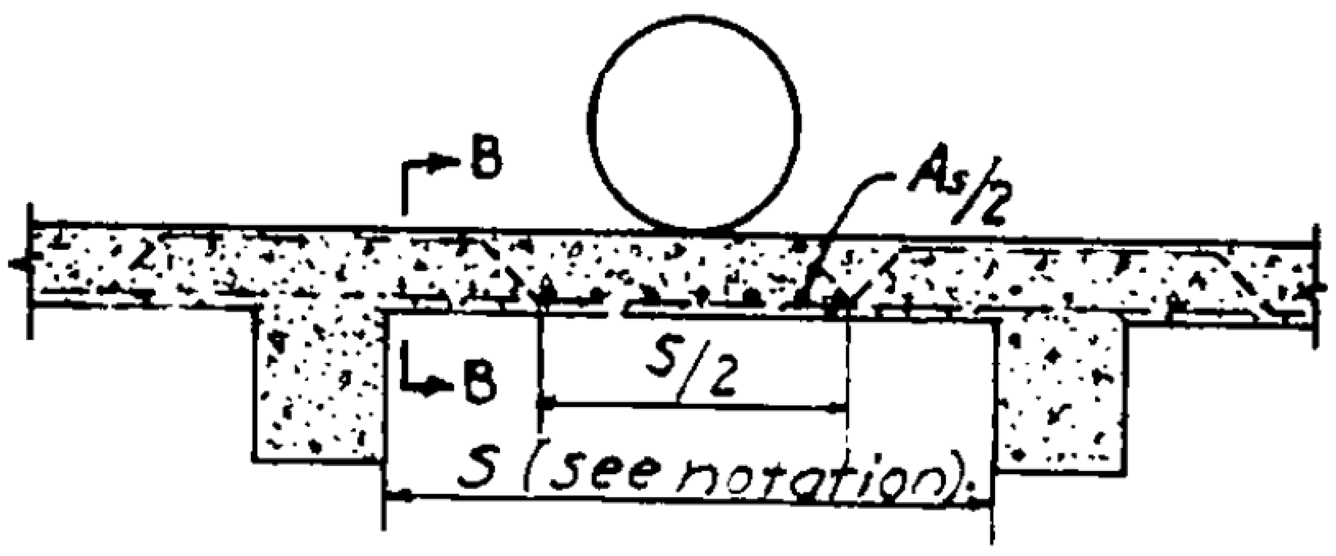


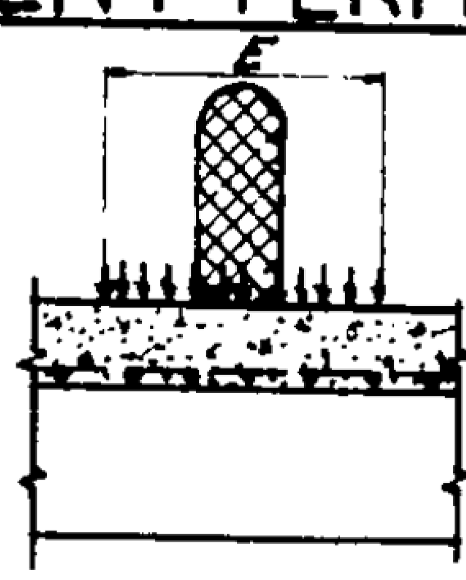
$S < 7$ ft. $E = 0.6\,S + 2.5$

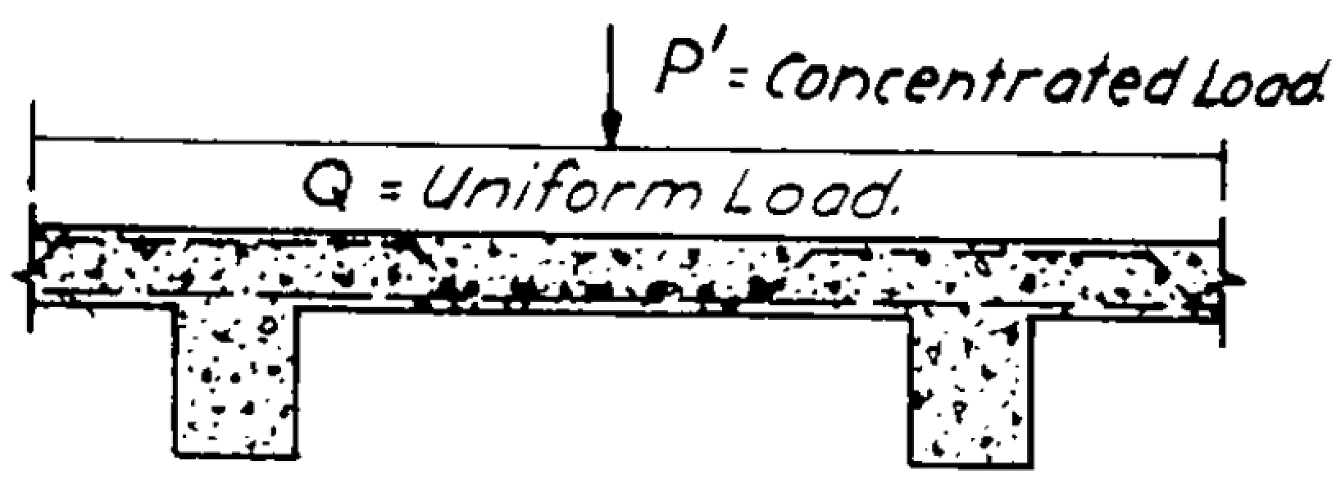
$S > 7$ ft. $E = 0.4\,S + 3.75$

SECTION A-A.

FIG. A - MAIN REINFORCEMENT PERPENDICULAR TO TRAFFIC.







$S < 12$ $E = 0.175\,S + 3.2$

$S > 12$ $E = \dfrac{10N + W}{4N}$

SECTION B-B.

Q distributed $= \dfrac{NQ}{0.5W + 5N}$ per sq. ft. of slab.

P' distributed $= \dfrac{NP'}{0.5W + 5N}$ per ft. width of slab.

TRUCK LOADING.

LANE LOADING.

FIG. B - MAIN REINFORCEMENT PARALLEL TO TRAFFIC.

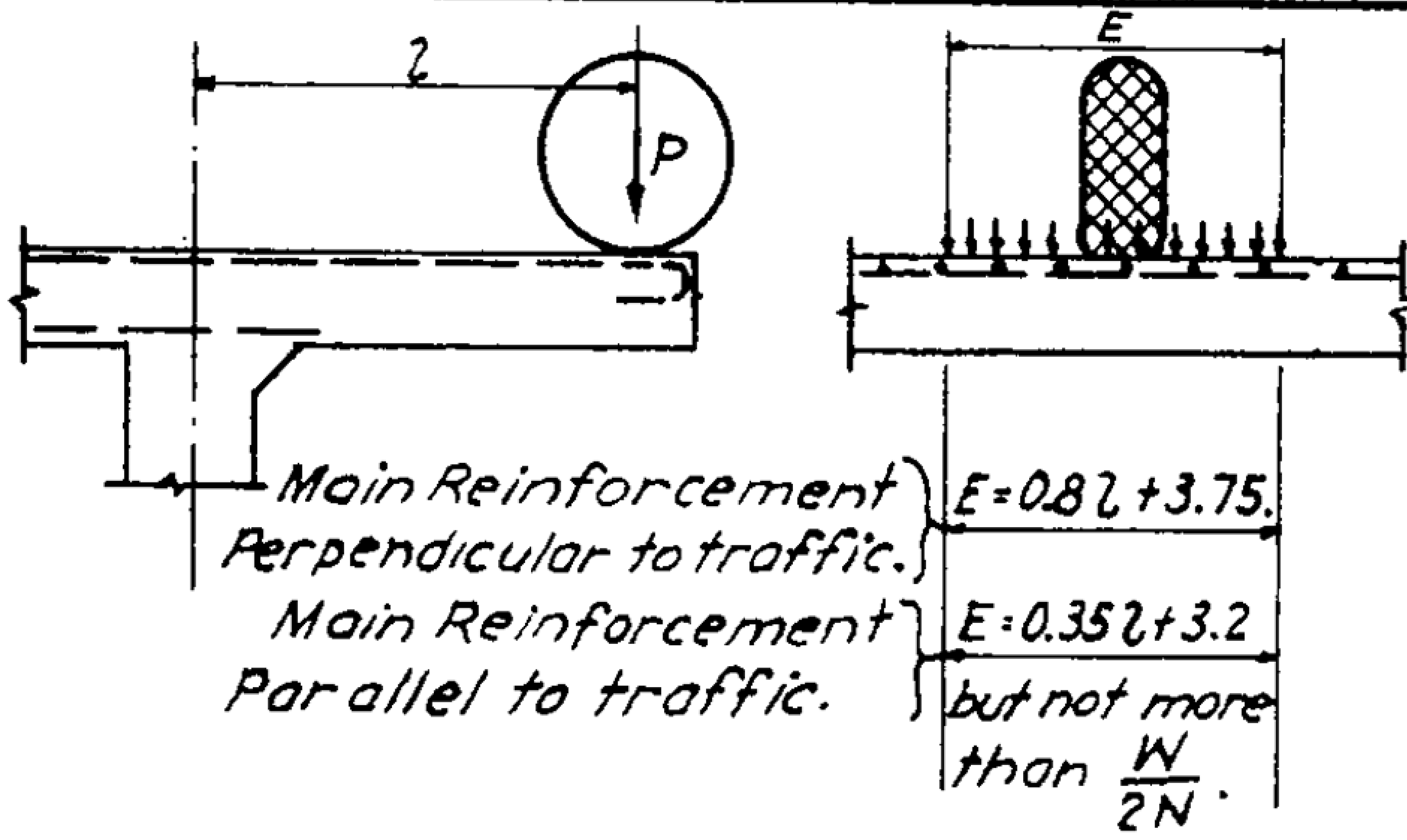


FIG. C - CANTILEVER SLABS.

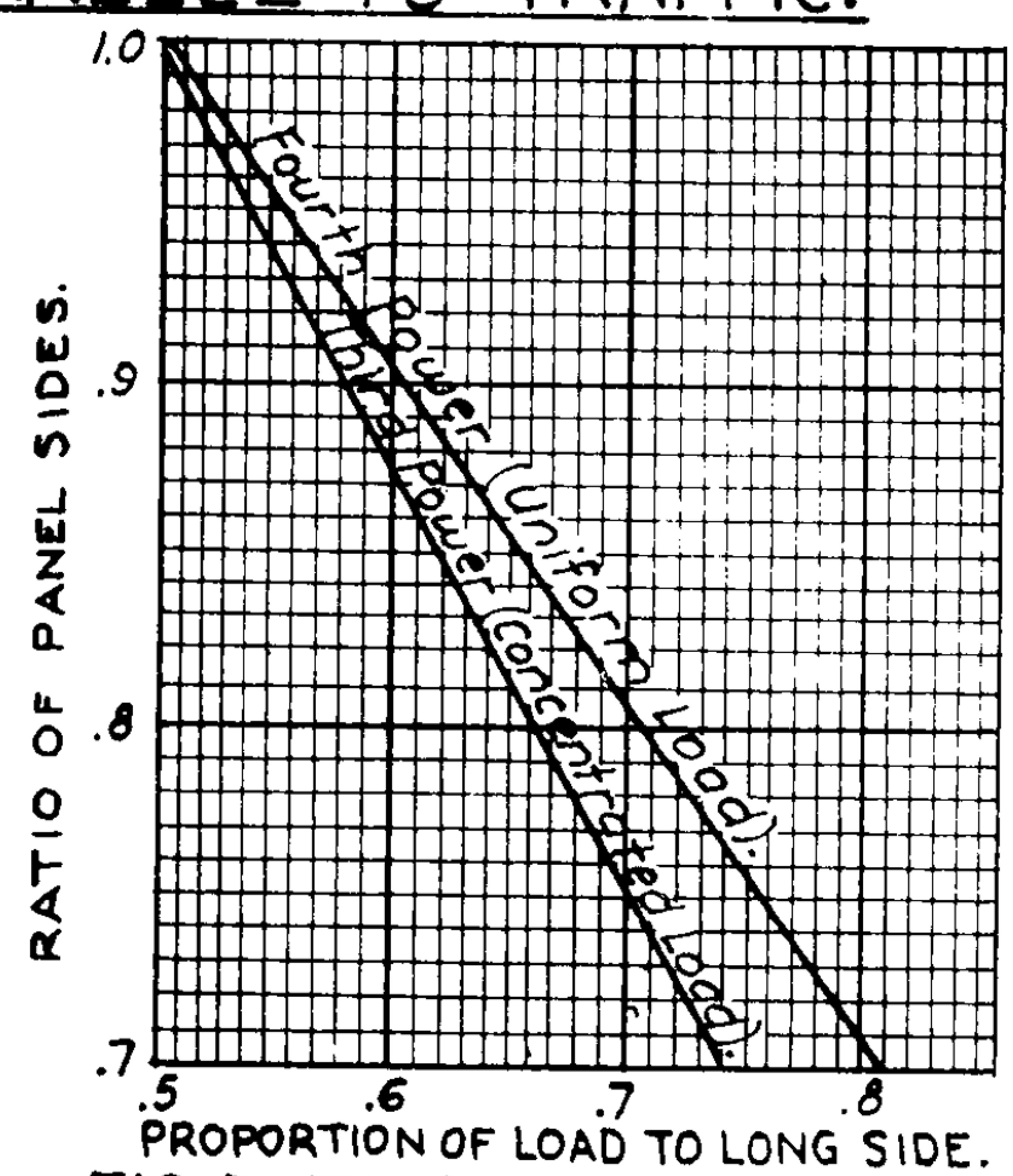


FIG. D - TWO-WAY SLABS.

Where ratio is less than 0.67 - design as one-way slab. Distribute loads as above.

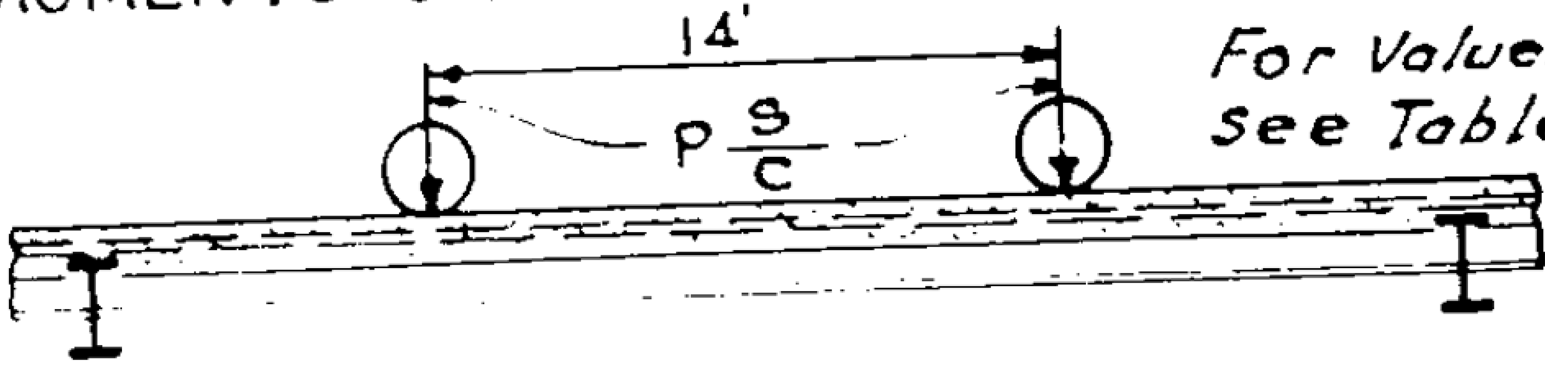
NOTES

1. Slabs designed for moment with loads distributed as above shall be considered adequate without shear reinf.
2. Provide edge beams where main reinforcement is parallel to traffic; curb section may be used. Live Load $M = .01\,PS^2$ for simple span; reduce 20% for continuous spans.
3. In designing slabs ℄ of wheel load shall be assumed to be 1' from curb face.

* In accord with A.A.S.H.O. specs.

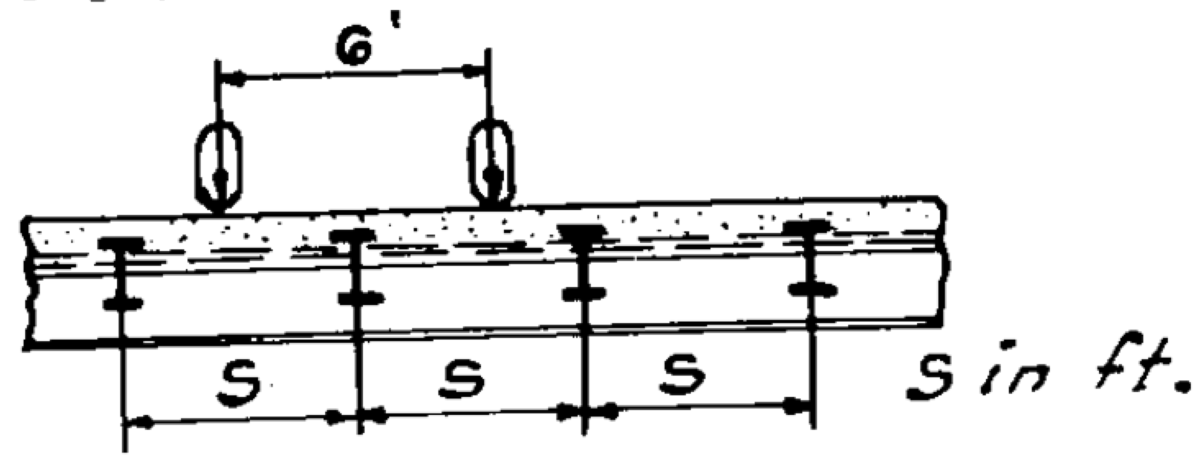
BRIDGES - LIVE LOAD DISTRIBUTION*-2

MOMENTS ON INTERIOR LONGITUDINAL FLOOR BEAMS & STRINGERS DUE TO WHEEL LOADS.



For Values of C see Table B.

LONGITUDINAL SECTION



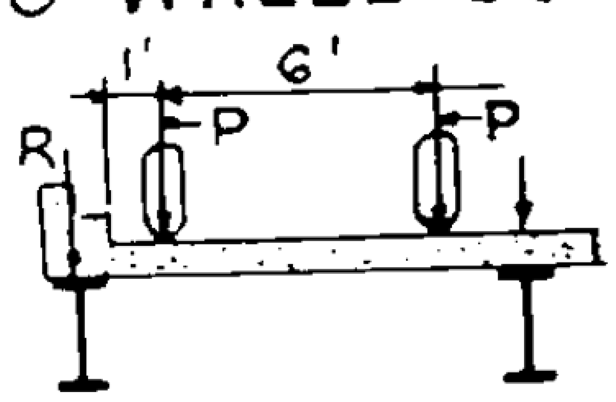
CROSS SECTION

FIG. A

TABLE B - VALUES OF C

KIND OF FLOOR	STRINGERS, TRAFFIC LANES: ONE	STRINGERS, TRAFFIC LANES: TWO OR MORE	KIND OF FLOOR	STRINGERS, TRAFFIC LANES: ONE	STRINGERS, TRAFFIC LANES: TWO OR MORE
PLANK	4.0	3.75	CONCRETE	6.0 (If $S>6.0$ see Note 1)	5.0 (If $S>10.5$ see Note 1)
STRIP 4" to 6"; Blocks on 4" Planks; Laminated 5"	4.5	4.0	STEEL GRID <4"	4.5	4.0
STRIP: 6" & > (See Note 2 below)	5.0 (If $S>5$ see Note 1)	4.25 (If $S>6.5$ see Note 1)	STEEL GRID 4" & >	6.0 (If $S>6.0$ see Note 1)	6.0 (If $S>10.5$ see Note 1)

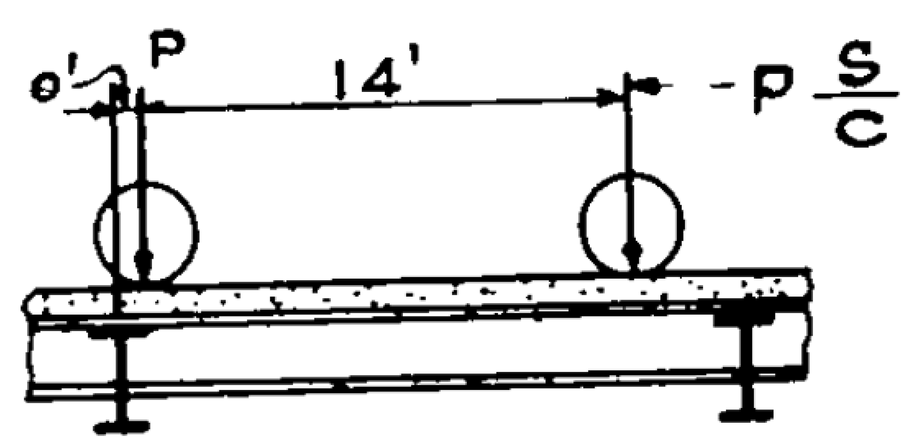
MOMENTS ON EXTERIOR LONGITUDINAL FLOOR BEAMS AND STRINGERS DUE TO WHEEL LOADS.



R = Reaction of P or P's, assuming slab acts as a simple beam between stringers.

FIG. C

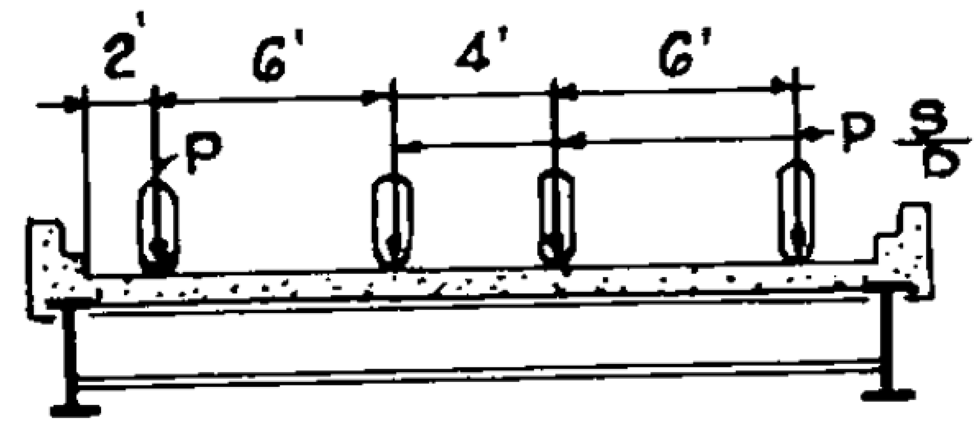
SHEAR & END REACTIONS FOR LONGITUDINAL & TRANSVERSE BEAMS DUE TO WHEEL LOADS.



Max. Shear = P + reaction of $P\frac{S}{C}$.

LONGITUDINAL BEAM

NOTE: See Tab. B for values of C. See Fig E for values of D.

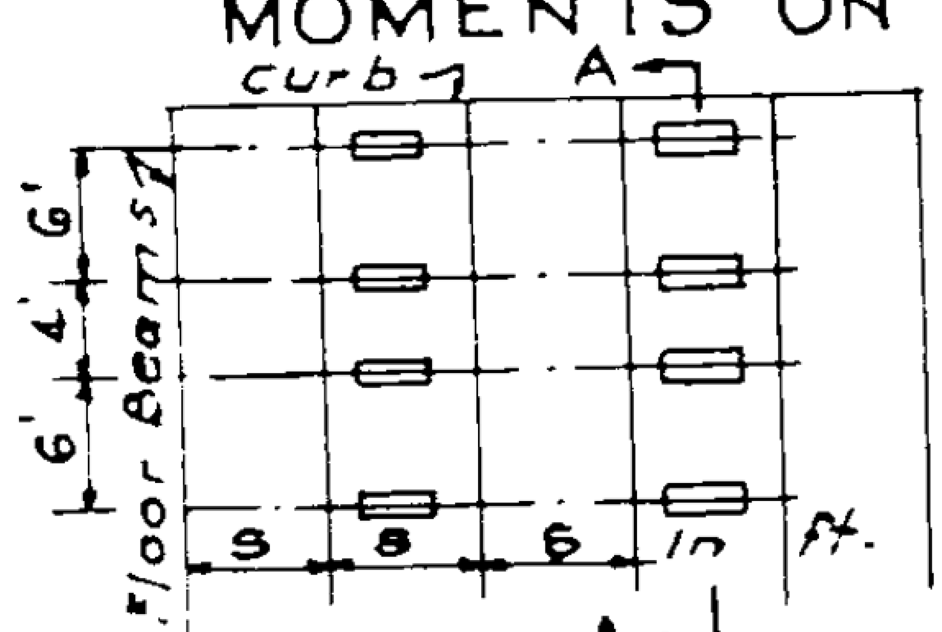


Max. Shear = Reaction of P + reactions of $P\frac{S}{D}$

TRANSVERSE BEAMS NO STRINGERS

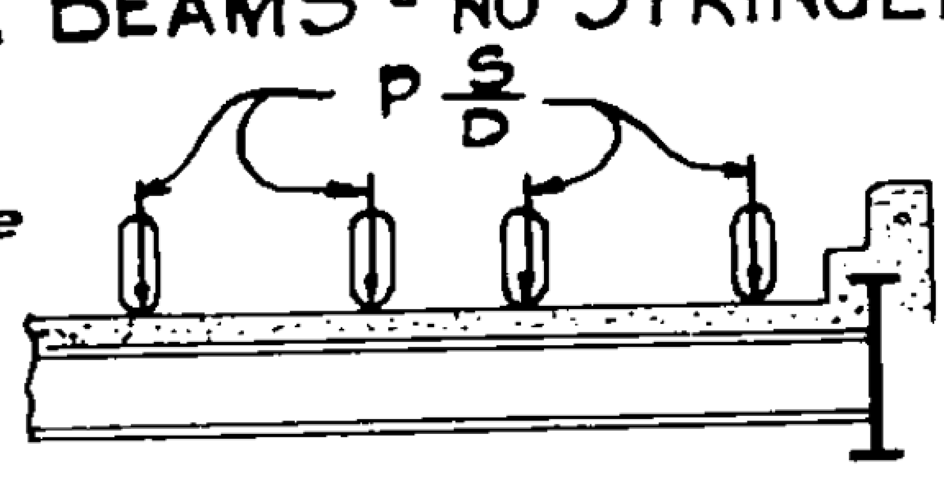
FIG. D

MOMENTS ON TRANSVERSE FLOOR BEAMS - NO STRINGERS.



PLAN

For Values of D use Table B above for ONE TRAFFIC LANE. If S greater than D, see Note 1 below.



SECTION A-A

FIG. E

NOTE: 1. In this case the load on each beam or stringer shall be the reaction of the wheel loads, assuming the flooring to act as a simple beam.

2. Strip flooring = planking on edge placed at right angles to ℄ of roadway, spiked together 18" o.c. and at ends; spike length = 2½ plank thickness minimum; toe nails or clips to alternate stringers. Spline, tongue and groove, and doweled flooring shall have the same distribution as strip flooring of equivalent thickness.

*In accord with A.A.S.H.O. Specifications.

BRIDGES - LIVE LOAD DISTRIBUTION* - 3

TIMBER FLOORING

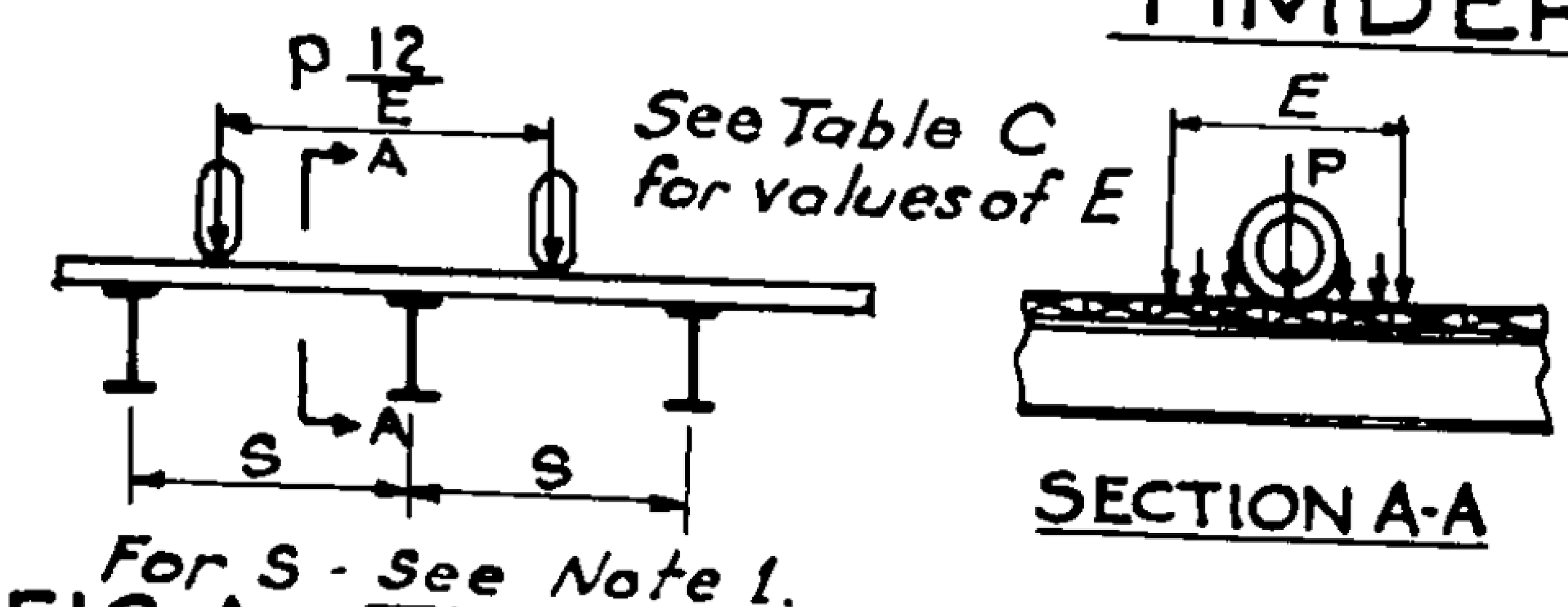


FIG. A - TRANSVERSE FLOORING.

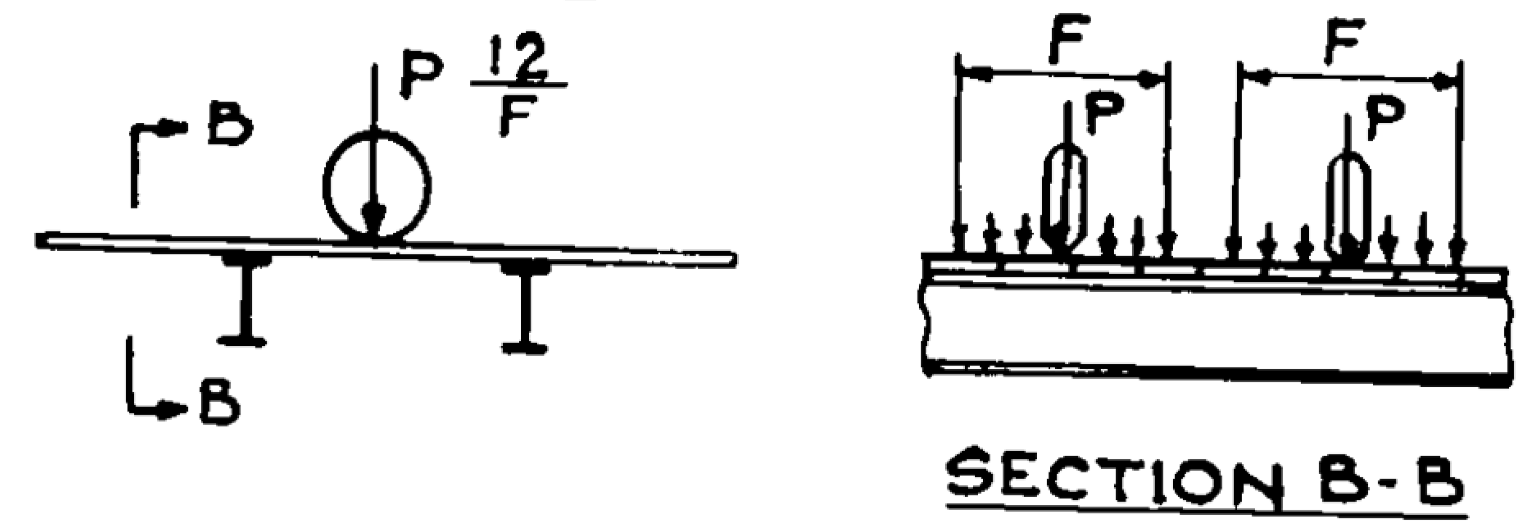


FIG. B - LONGITUDINAL FLOORING.

TABLE C - VALUES OF E & F.

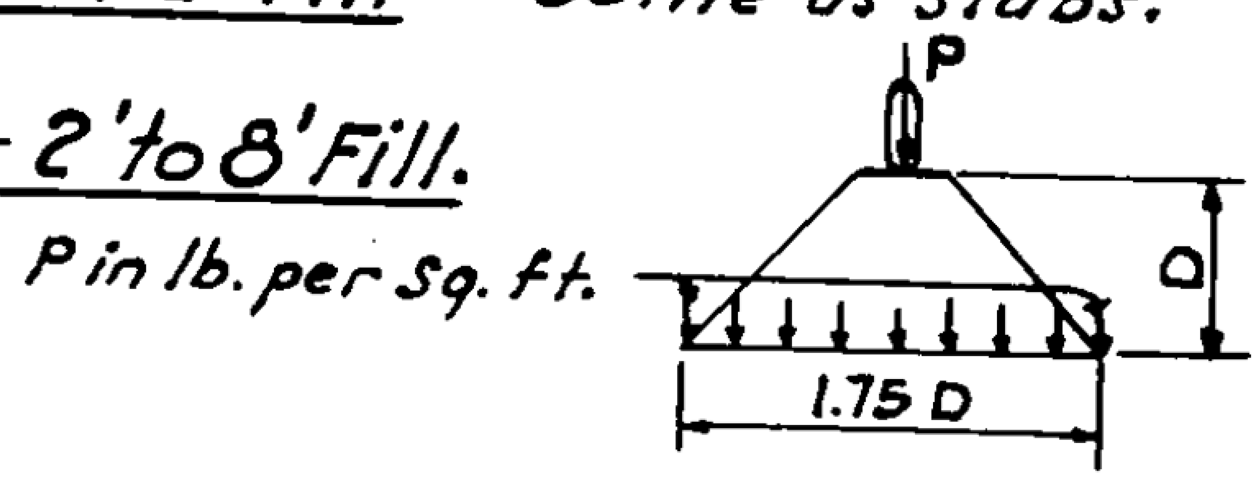
TYPE OF FLOOR		E	F
Plank	Free Edges	Width of Plank in Inches.	Width of Plank in Inches.
Plank	Laminated	15"	1" x gross wt. of truck in tons + floor thickness in inches.
Plank	Tongue & Groove; Spline & Doweled not < 5½" thick.	Four times floor thickness in inches.	1" x gross wt. of truck in tons + 2 x floor thickness in inches.

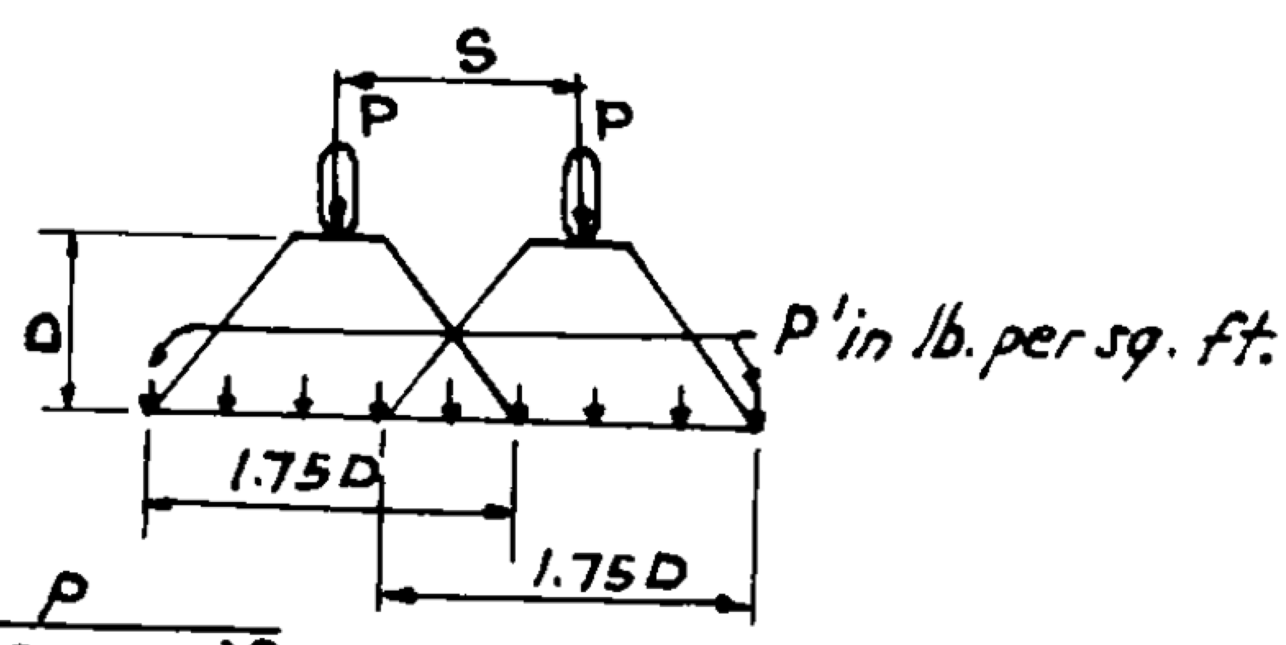
NOTE 1: Span length = Clear distance between stringers or beams + ½ width of stringer or beam, but not over clear span + floor thickness.

DISTRIBUTION THRU EARTH FILLS.

Case I - < 2' Fill - same as slabs.

Case II - 2' to 8' Fill.





P' in lb. per sq. ft. $= \dfrac{P}{(1.75)^2}$ $\qquad P' = \dfrac{P}{(1.75D+S)^2}$

Case III - > 8' Fill - neglect if depth > span length.

STEEL GRID FLOORS.

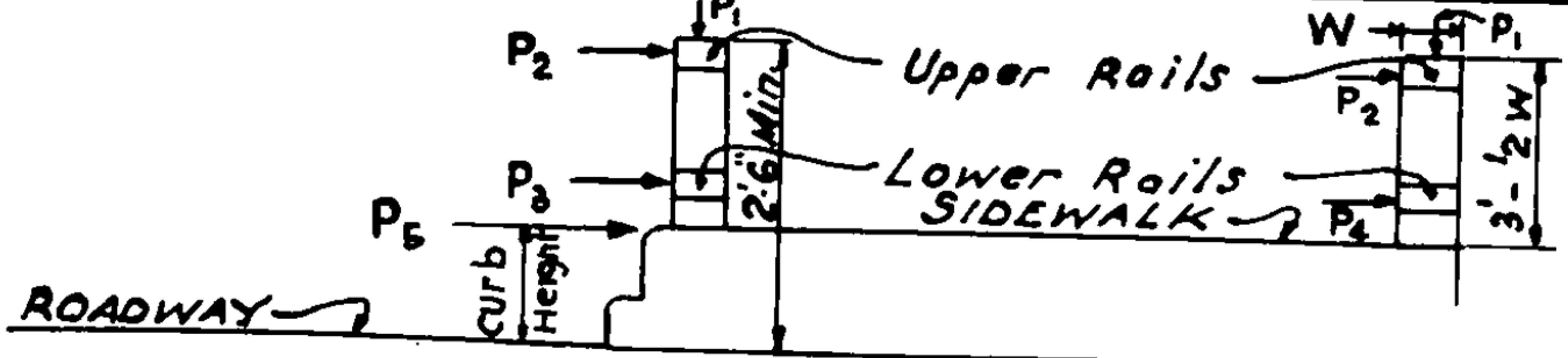
Case I - Filled with concrete - same as slabs, Pg. 4-53.

Case II - Open - Distribute normal to main bars over width of wheel. (1" x gross weight of truck in tons) + 2 x main bar spacing in inches.

ELECTRIC RAILWAY LOADS.

Distribute wheel loads longitudinally 3 ft.; transversely (on ties and ballast construction) 10' per axle load.

CURB AND RAILING LOADS.



NOTE: See Pg. 3-67 for additional curb and railing dimensions and criteria.

P_1 = 100 lb. per lin. ft. at top.
P_2 = 150 lb. per lin. ft. at top.
P_3 = Curb ht. < 10" - 300 lb. per lin. ft. on lower rail, or if no lower rail 300 lb. per lin. ft. on web members 1'9" above roadway.
Curb ht. 10" to 20". Reduce 300 lb. by 15 lb. per inch ht.
over 20" Curb ht. - 150 lb. per Lin. ft.
P_4 = Same as P_3 except omit where trusses, girders, arches, or curb railings protect sidewalk railings.
P_5 = 500 lb. per Lin. ft. of curb at curb height up to 10" max.

* In accord with A.A.S.H.O. Specifications.

BRIDGES - LOADING TABLES AND DETAILS

TABLE A - MAXIMUM MOMENTS, SHEARS & REACTIONS - SIMPLE SPANS, ONE LANE (10')*

SPAN IN FT.	H 15 MOMENT	H 15 END SHEAR & END REACT. (a)	H15-S12 MOMENT	H15-S12 END SHEAR & END REACT. (a)	H 20 MOMENT	H 20 END SHEAR & END REACT. (a)	H20-S16 MOMENT	H20-S16 END SHEAR & END REACT. (a)
1	6.0(b)	24.0(b)	6.0	24.0	8.0(b)	32.0(b)	8.0	32.0
2	12.0(b)	24.0(b)	12.0	24.0	16.0(b)	32.0(b)	16.0	32.0
3	18.0(b)	24.0(b)	18.0	24.0	24.0(b)	32.0(b)	24.0	32.0
4	24.0(b)	24.0(b)	24.0	24.0	32.0(b)	32.0(b)	32.0	32.0
5	30.0(b)	24.0(b)	30.0	24.0	40.0(b)	32.0(b)	40.0	32.0
6	36.0(b)	24.0(b)	36.0	24.0	48.0(b)	32.0(b)	48.0	32.0
7	42.0(b)	24.0(b)	42.0	24.0	56.0(b)	32.0(b)	56.0	32.0
8	48.0(b)	24.0(b)	48.0	24.0	64.0(b)	32.0(b)	64.0	32.0
9	54.0(b)	24.0(b)	54.0	24.0	72.0(b)	32.0(b)	72.0	32.0
10	60.0(b)	24.0(b)	60.0	24.0	80.0(b)	32.0(b)	80.0	32.0
11	66.0(b)	24.0(b)	66.0	24.0	88.0(b)	32.0(b)	88.0	32.0
12	72.0(b)	24.0(b)	72.0	24.0	96.0(b)	32.0(b)	96.0	32.0
13	78.0(b)	24.0(b)	78.0	24.0	104.0(b)	32.0(b)	104.0	32.0
14	84.0(b)	24.0(b)	84.0	24.0	112.0(b)	32.0(b)	112.0	32.0
15	90.0(b)	24.4(b)	90.0	25.6	120.0(b)	32.5(b)	120.0	34.1
16	96.0(b)	24.8(b)	96.0	27.0	128.0(b)	33.0(b)	128.0	36.0
17	102.0(b)	25.1(b)	102.0	28.2	136.0(b)	33.4(b)	136.0	37.7
18	108.0(b)	25.3(b)	108.0	29.3	144.0(b)	33.8(b)	144.0	39.1
19	114.0(b)	25.6(b)	114.0	30.3	152.0(b)	34.1(b)	152.0	40.4
20	120.0(b)	25.8(b)	120.0	31.2	160.0(b)	34.4(b)	160.0	41.6
21	126.0(b)	26.0(b)	126.0	32.0	168.0(b)	34.7(b)	168.0	42.7
22	132.0(b)	26.2(b)	132.0	32.7	176.0(b)	34.9(b)	176.0	43.6
23	138.0(b)	26.3(b)	138.0	33.4	184.0(b)	35.1(b)	184.0	44.5
24	144.0(b)	26.5(b)	144.5	34.0	192.0(b)	35.3(b)	192.7	45.3
25	150.0(b)	26.6(b)	155.5	34.6	200.0(b)	35.5(b)	207.4	46.1
26	156.0(b)	26.8(b)	166.6	35.1	208.0(b)	35.7(b)	222.2	46.8
27	162.7(b)	26.9(b)	177.8	35.6	216.9(b)	35.9(b)	237.0	47.4
28	170.1(b)	27.0(b)	189.0	36.0	226.8(b)	36.0(b)	252.0	48.0
29	177.5(b)	27.1(b)	200.3	36.6	236.7(b)	36.1(b)	267.0	48.8
30	185.0(b)	27.2(b)	211.6	37.2	246.6(b)	36.3(b)	282.1	49.6
31	192.4(b)	27.3(b)	223.0	37.7	256.5(b)	36.4(b)	297.3	50.3
32	199.8(b)	27.4(b)	234.4	38.3	266.5(b)	36.5(b)	312.5	51.0
33	207.3(b)	27.5(b)	245.8	38.7	276.4(b)	36.6(b)	327.8	51.6
34	214.7(b)	27.7	257.7	39.2	286.3(b)	36.9	343.5	52.2
35	222.2(b)	27.9	270.9	39.6	296.2(b)	37.2	361.2	52.8
36	229.6(b)	28.1	284.2	40.0	306.2(b)	37.5	378.9	53.3
37	237.1(b)	28.4	297.5	40.4	316.1(b)	37.8	396.6	53.8
38	244.5(b)	28.6	310.7	40.7	326.1(b)	38.2	414.3	54.3
39	252.0(b)	28.9	324.0	41.1	336.0(b)	38.5	432.1	54.8
40	259.5(b)	29.1	337.4	41.4	346.0(b)	38.8	449.8	55.2

SPAN IN FT.	H 15 MOMENT	H 15 END SHEAR & END REACT. (a)	H15-S12 MOMENT	H15-S12 END SHEAR & END REACT. (a)	H 20 MOMENT	H 20 END SHEAR & END REACT. (a)	H20-S16 MOMENT	H20-S16 END SHEAR & END REACT. (a)
42	274.4(b)	29.6	357.8	40.1	365.9(b)	39.4	477.1	53.4
44	289.3(b)	30.1	380.2	40.6	385.8(b)	40.1	506.9	54.1
46	304.3(b)	30.5	403.0	41.0	405.7(b)	40.7	537.3	54.7
48	319.2(b)	31.0	426.2	41.5	425.6(b)	41.4	568.3	55.4
50	334.2(b)	31.5	450.0	42.0	$\boxed{445.6(b)}$	$\boxed{42.0}$	600.0	56.0
52	349.1(b)	32.0	474.2	42.5	465.5(b)	42.6	632.3	56.6
54	364.1(b)	32.5	499.0	43.0	485.5(b)	43.3	665.3	57.3
56	379.1(b)	32.9	524.2	43.4	505.4(b)	43.9	698.9	57.9
58	397.6	33.4	549.8	43.9	530.1	44.6	733.1	58.6
60	418.5	33.9	576.0	44.4	558.0	45.2	768.0	59.2
62	439.9	34.4	602.6	44.9	586.5	45.8	803.5	59.8
64	461.8	34.9	629.8	45.4	615.7	46.5	839.7	60.5
66	484.1	35.3	657.4	45.8	645.5	47.1	876.5	61.1
68	506.9	35.8	685.4	46.3	675.9	47.8	913.9	61.8
70	530.3	36.3	714.0	46.8	707.0	48.4	952.0	62.4
75	590.6	37.5	787.5	48.0	787.5	50.0	1,050.0	64.0
80	654.0	38.7	864.0	49.2	872.0	51.6	1,152.0	65.6
85	720.4	39.9	943.5	50.4	960.5	53.2	1,258.0	67.2
90	789.8	41.1	1,026.0	51.6	1,053.0	54.8	1,368.0	68.8
95	862.1	42.3	1,115.5	52.8	1,149.5	56.4	1,482.0	70.4
100	937.5	43.5	1,200.0	54.0	1,250.0	58.0	1,600.0	72.0
110	1,097.3	45.9	1,386.0	56.4	1,463.0	61.2	1,848.0	75.2
120	1,269.0	48.3	1,584.0	58.8	1,692.0	64.4	2,112.0	78.4
130	1,452.8	50.7	1,794.0	61.2	1,937.0	67.6	2,392.0	81.6
140	1,648.5	53.1	2,016.0	63.6	2,198.0	70.8	2,688.0	84.8
150	1,856.3	55.5	2,250.0	66.0	2,475.0	74.0	3,000.0	88.0
160	2,076.0	57.9	2,496.0	68.4	2,768.0	77.2	3,328.0	91.2
170	2,307.8	60.3	2,754.0	70.8	3,077.0	80.4	3,672.0	94.4
180	2,551.5	62.7	3,024.0	73.2	3,402.0	83.6	4,032.0	97.6
190	2,807.3	65.1	3,306.0	75.6	3,743.0	86.8	4,408.0	100.8
200	3,075.0	67.5	3,600.0	78.0	4,100.0	90.0	4,800.0	104.0
220	3,646.5	72.3	4,224.0	82.8	4,862.0	96.4	5,632.0	110.4
240	4,266.0	77.1	4,896.0	87.6	5,688.0	102.8	6,528.0	116.8
260	4,933.5	81.9	5,616.0	92.4	6,578.0	109.2	7,488.0	123.2
280	5,649.0	86.7	6,384.0	97.2	7,532.0	115.6	8,512.0	129.6
300	6,412.5	91.5	7,200.0	102.0	8,550.0	122.0	9,600.0	136.0

Notes:- Moments given in foot kips; End shears given in kips = 1000 lbs.
Reduce for multiple lane loading. Add for impact.
(a) Concentrated load at support, shear loads used.
(b) Value determined by Truck Loading.

USE OF TABLE

Given H-20 Loading, Clear stringer span 50', 2-Stringers per lane (5' stringer spacing). Required - Max. Stringer Mom. and End Reaction. Solution - End Shear = 42 k, Mom. = 445.6 ft. Kips. Stringer shear = $\frac{42}{2}$ = 21 k; Stringer Mom. = $\frac{445.6}{2}$ = 222.8 ft. kips. For Concrete Slabs Reinforced Parallel to Traffic, divide values in Table by 10 to give shear and moment per ft. of width.

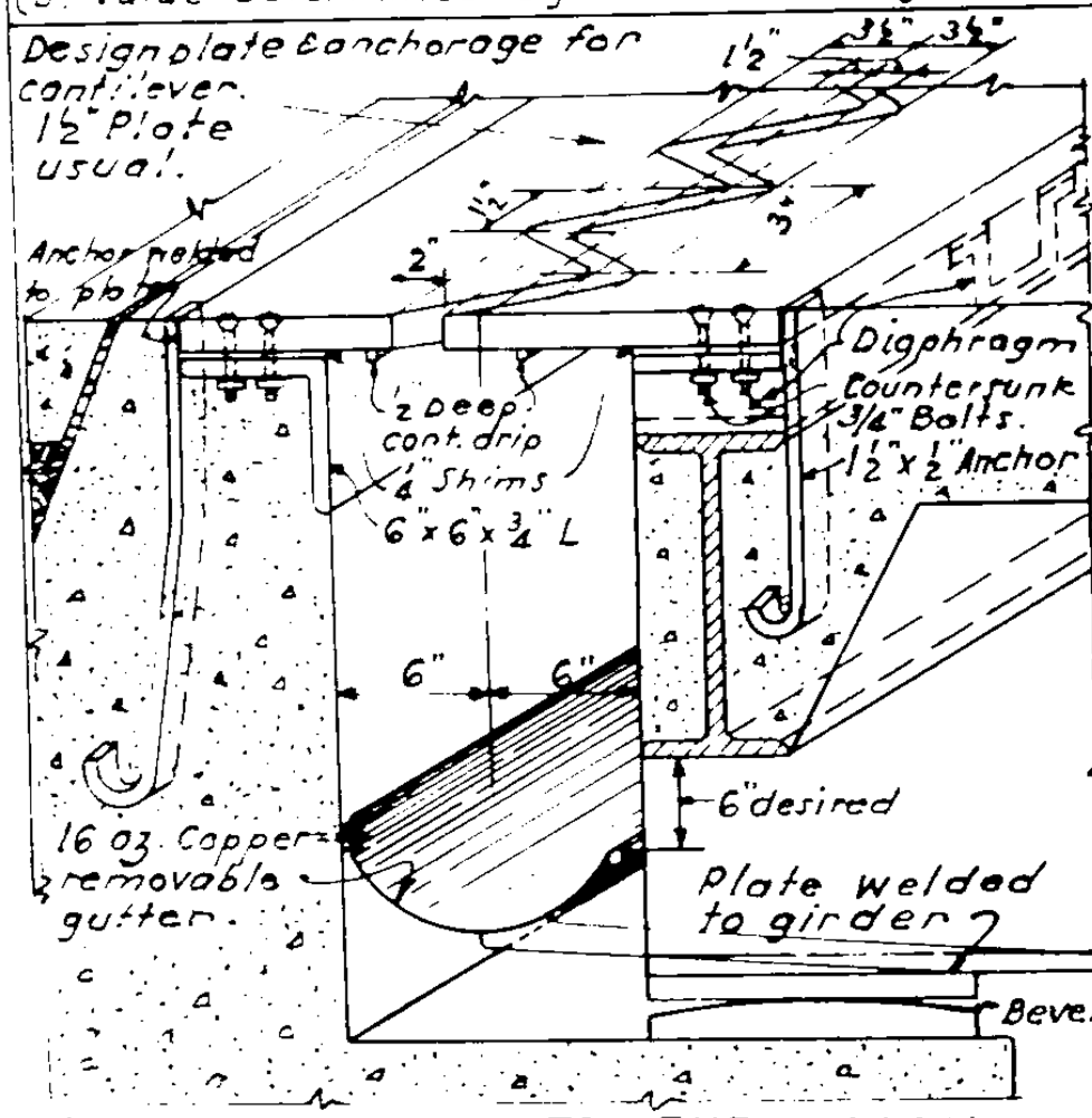


FIG. B - PROVISION FOR EXPANSION.
Max. span with no provision = 20 feet.
Slip joint - Spans up to 70', Spans over 70' use rollers.

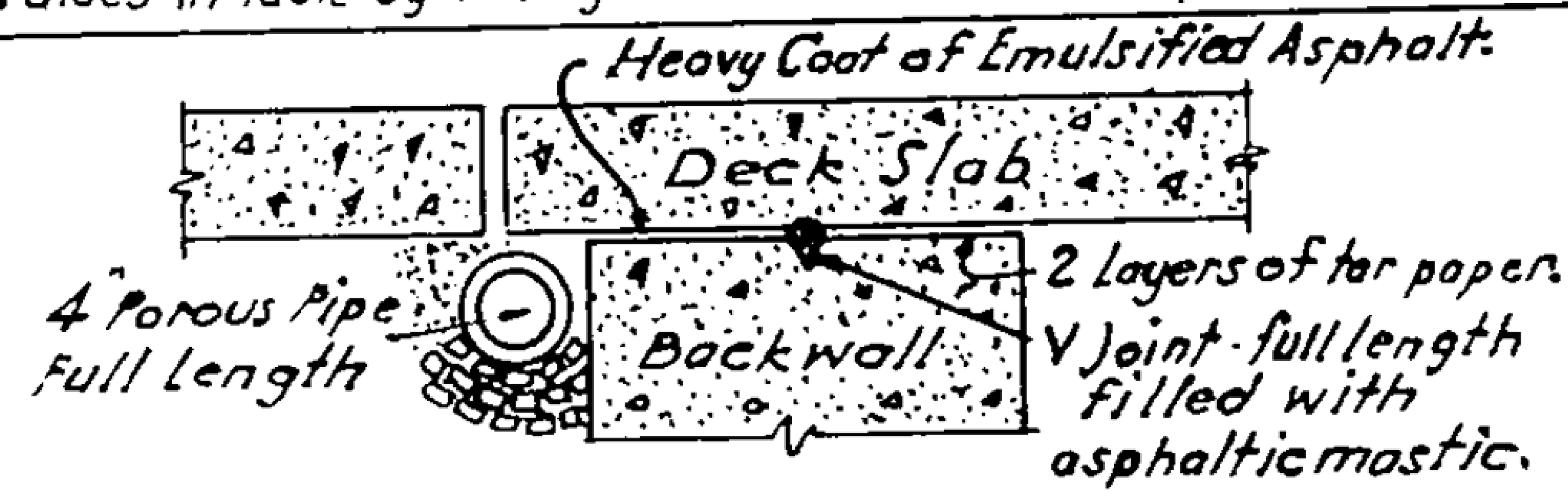


FIG. C - DECK SLAB AT ABUTMENT.
(After detail of Pennsylvania R.R.)

FLUE BLAST PROTECTION OVER RAILROAD.*

For metal or concrete < 20 feet clear.
Use ¾" C.I.; ⅜" W.I.; ½" Plain Asbestos Board, or 7/16" Concrete Asbestos Board.
Bolts shall be not less than ⅝" ϕ.
All fastenings galvanized.

SUPERELEVATION:*

Not > 0.10 foot per foot of width.

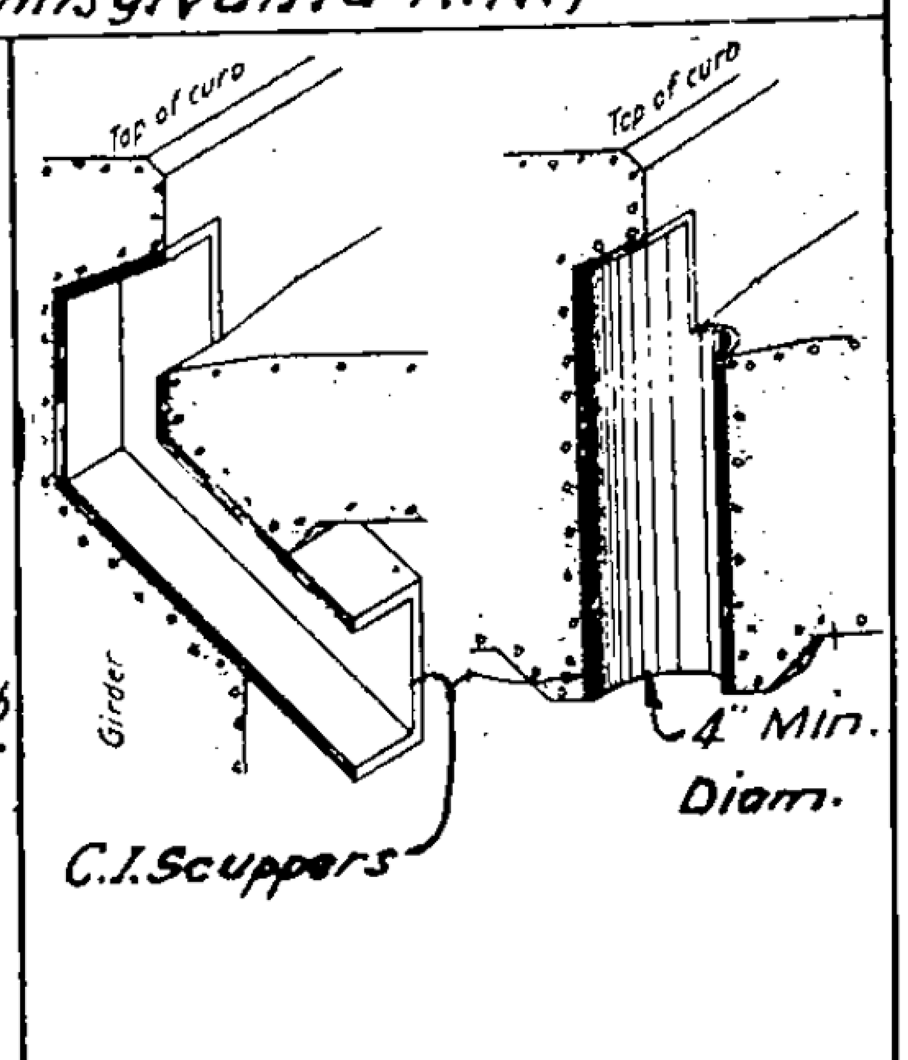


FIG. D - SCUPPERS.**

*Adapted from A.A.S.H.O. Specs. ** Adapted from Portland Cement Assoc.

BRIDGES - UNIT STRESSES-1

NOTES: 1. All stresses adapted from A.A.S.H.O. and A.R.E.A. specifications.
2. Stresses followed by an asterisk (*) apply only to Highways; stresses followed by a dagger ( ) apply only to Railroads.
3. For wood stresses use pg. 1-03 and 1-04 decreased 20%.

STRESS APPLICATION - HIGHWAY BRIDGES

Group A		Group B	
Dead Load	Buoyancy	Long. Forces	Erection Stresses
Live Load	Earth Pressure	Wind	Ice
Impact		Shrinkage Stresses	Current
		Centrifugal Forces	Earthquake
		Rib Shortening	Thermal Stresses

Use unit stresses shown for Group A loads. Use unit stresses + 25% when Group B loads are combined with Group A loads.

STEEL - stress in p.s.i. except as noted

Structural Carbon Steel (A.S.T.M. - A 7)
Rivet Steel (A.S.T.M. - A 141)
Pins and Rollers (A.S.T.M. - A 235, Class C1) *

Axial tension, structural steel, net section	18,000
Tension in extreme fibers of rolled shapes, girders, and built sections subject to bending	18,000
Tension in bolts at root of thread *	13,500
Axial compression, gross section: stiffeners of plate girders	18,000
Columns centrally loaded and with values of L/r not greater than 140: Riveted ends	$15{,}000 - 1/4\ L^2/r^2$
Pin ends	$15{,}000 - 1/3\ L^2/r^2$

L = length of member, in inches.
r = least radius of gyration of member, in inches.

For compression members with values of L/r greater than 140, and for compression members of known eccentricity, use secant formulas in A.A.S.H.O. or A.R.E.A. Bridge Specifications.

Compression in extreme fibers of rolled shapes, girders, and built sections subject to bending (for values of L/b not greater than 40) . . . $18{,}000 - 5L^2/b^2$

L = length, in inches, of unsupported flange between lateral connections or knee braces, and b = flange width, in inches.

Allowable compression in splice material, gross section *	18,000
Stress in extreme fiber of pins	27,000
Shear in plate girder webs, gross section	11,000
Diagonal tension in webs of girders and rolled beams at sections where maximum shear and bending occur simultaneously.	18,000
Shear in power-driven rivets and pins	13,500
Shear in turned bolts	11,000
Shear in hand-driven rivets	11,000
Bearing on pins	24,000
Bearing on power-driven rivets, milled stiffeners, and other steel parts in contact (Rivets driven by pneumatically or electrically operated hammers are considered power driven)	27,000
Bearing between rockers and rocker pins	12,000
Bearing on pins subject to rotation *	12,000
Bearing on turned bolts	20,000
Bearing on hand-driven rivets	20,000
Bearing on expansion rollers and rockers, pounds per linear inch:	
Diameters up to 25 in.	$\frac{p - 13{,}000}{20{,}000}\ 600d$
Diameters from 25 to 125 in.	$\frac{p - 13{,}000}{20{,}000}\ 3{,}000\sqrt{d}$

d = diameter of roller or rocker, in inches
p = yield point in tension of steel in the roller or the base, whichever is the lesser.

In proportioning rivets the nominal diameter shall be used. The effective bearing area of a pin, a bolt, or a rivet shall be its diameter multiplied by the thickness of the metal on which it bears. In metal less than 3/8 in. thick countersunk rivets shall not be assumed to carry stress; in metal 3/8 in. thick and over, one-half the depth of countersink shall be omitted in calculating bearing area.* For countersunk rivets deduct one half depth of countersink.†

<u>High Strength Rivets</u> * (A.S.T.M. - A 195)	
Shear	20,000
Bearing	40,000
<u>Wrought Iron</u> * (A.S.T.M. - A 207, for shapes and bars; A.S.T.M. - A 42, for plates; A.S.T.M. - A 72, for pipe) Tension	14,000
Bending on extreme fiber	14,000
<u>Cast Steel</u> For cast steel the allowable unit stresses in compression and bearing shall be the same as those for structural steel. Other allowable unit stresses shall be three-fourths of those for structural steel.	
<u>Cast Iron</u>* (A.S.T.M. - A 48 - Class 30).	
Bending on extreme fiber	3,000
Shear	3,000
Direct compression (short columns)	12,000
<u>Bronze or Copper Alloy</u> *	
Bearing on bronze or copper alloy bearing and expansion plates	2,000
<u>Bearing on Masonry</u>	
Bearing on granite masonry	800
Bearing on sandstone and limestone masonry	400

BRIDGES - UNIT STRESSES-2

Bearing on concrete: *

Bridge seats, under hinged rockers and bolsters (not subjected to high edge loading by a deflecting beam, girder, or truss) 1,000

Bridge seats, under bearing plates or nonhinged shoes (subjected to high edge loading by the direct bearing, upon the plate or shoe, of a deflecting beam or girder), average 700

(The above bridge seat unit stresses will apply only where the edge of bridge seat projects at least 3 in., average, beyond edge of shoe or plate. Otherwise, the unit stresses permitted will be 75% of the above amounts.)

Bearing on concrete† 600

<u>Timber Cross Ties†</u>

Extreme fiber stress in bending:

Yellow pine, dense structural grade 1,500

Douglas fir, close grain structural grade 1,400

White oak 1,200

White pine, Norway pine, and spruce 800

<u>Slenderness Ratio†</u> = $\frac{\text{Length in inches}}{\text{Least radii of gyration}}$; not over 100 for main compression members, 120 for wind and sway bracing in compression, 140 for single lacing, 200 for double lacing, 200 for tension members other than eyebars.

CONCRETE FOR HIGHWAY BRIDGES

The unit stresses are based upon the use of concrete having an ultimate compressive strength at 28 days of 3,000 lb. For concrete having a less strength, the unit stresses shall be proportionately reduced.

If concrete having a higher strength than 3,000 lb. at 28 days can be produced, the stresses below, except bond on piling, may be modified as follows:

The allowable stresses may be increased proportionately with the extreme upper limit which may be used in computing working stresses at 4,500 lb./sq. in.

When stresses other than those specified in the table are used, the allowable stresses used and the ultimate strength of concrete upon which they are based shall be noted on the plans.

The stresses set forth may be increased 50% for concrete culverts when the depth of cover exceeds 8 ft.

<u>Direct compression:</u>

Bearing on bridge seats - see Bearing on masonry above.

In the following formulas:

L = unsupported length of member in feet.

D = least dimension of column section in feet.

n = ratio = $\frac{\text{Modulus of elasticity of steel}}{\text{Modulus of elasticity of conc.}}$ = 10 for 3,000# concrete and 12 for concrete under 3,000.

Piers and pedestals $\frac{L}{D}$ not over 3 600

Columns - axially loaded - with lateral ties.

$\frac{L}{D}$ not over 12

Safe load, $P = 600A\left[1 + (n-1)\,p\right]$

in which A = gross area in square inches.

p = percentage of main steel based on gross area.

Spiral columns = axially loaded - with spiral reinforcement.

Safe load, $P = A_c\left[1 - (n-1)\,p\right] f_c$

In which A_c = area within outer circumference of spiral hooping.

p = percentage of main steel based on area A_c.

f_c = (.25 - 12p) 3,000, p being ratio of volume of spiral reinforcement to volume of core.

Long columns $\frac{L}{D}$ in excess of 12.

(with lateral ties or spiral reinforcement)

Safe load = $P = \left(1.33 - \frac{L}{36D}\right) P$

in which P = safe load, formula for columns having $\frac{L}{D}$ less than 12.

<u>Compression in extreme fiber:</u>

Extreme fiber stress in flexure 1,000

Bending in columns (with lateral ties):

Extreme fiber stress (flexure and direct stress) 1,000

Bending in columns with spiral reinforcement:

Extreme fiber stress (flexure and direct stress) 1,250

<u>Tension:</u>

In reinforced concrete members . . . . None

In plain concrete (primarily footings) 75

<u>Shearing stresses:</u>

Beams without web reinforcement:

Longitudinal bars not anchored 60

Longitudinal bars anchored 90

Beams with web reinforcement:

Longitudinal bars not anchored 140

Longitudinal bars anchored 180

Punching shear 160

Bond on piles (in seals)

Timber, steel or concrete piles, 10 lb./sq. in.

(Providing the pile has the resistance to pull thereby induced.)

Coefficients.

Thermal, .000006. Shrinkage, .0002.

<u>Steel reinforcement:</u>

Tension in flexural members 18,000

Tension in web reinforcement 16,000

Compression . . . . n times the compression in the surrounding concrete

<u>Bond:</u>

Bars not anchored 100

Bars adequately anchored by hooks or otherwise 150

TRANSMISSION TOWERS - LIVE LOADS & UNIT STRESSES

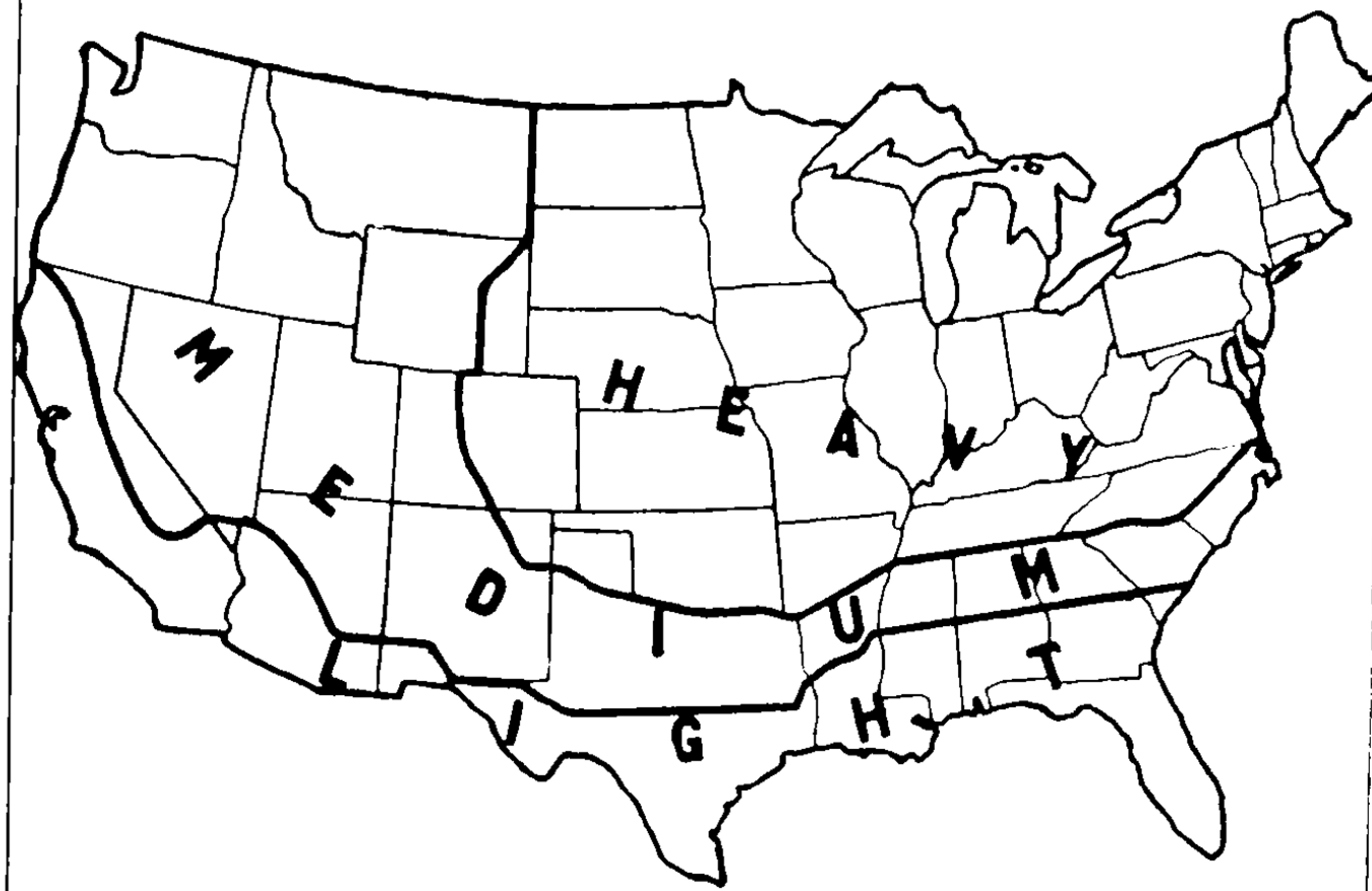


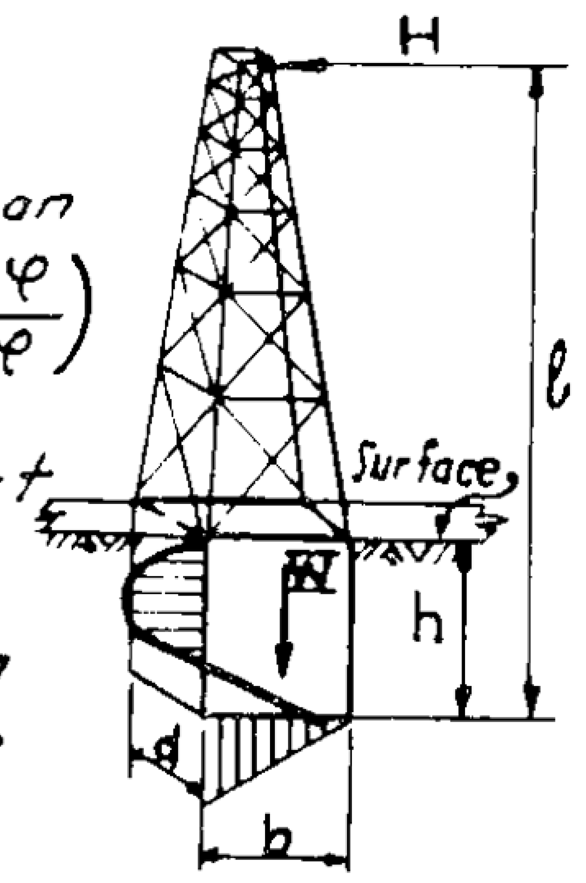
FIG. A - DISTRICT LOADING MAP.*

$$\frac{3}{2}h\left(Hl - \frac{wb}{6}\right)$$

must be less than

$$\frac{dwh^2}{8}\left(\frac{1+\sin\varphi}{1-\sin\varphi}\right)$$

and $\frac{2\underline{W}}{db}$ must be less than safe bearing value of soil.



h = depth in ft. below surface.
H = Horizontal force.
$\underline{W}$ = Total vertical force.
W = Weight of earth per cu. ft.
φ = Angle of repose.

Approx. solution by Author.

FIG. B - DESIGN OF TOWER FOUNDATION ALLOWING FOR PASSIVE RESISTANCE OF SOIL.

TABLE C - LOADS ON TOWER.*

LONGITUDINAL

1. Unbalanced loads due to change in grade of construction, broken wires, jointly used poles, dead ends, and any other unbalanced conductors.

VERTICAL

1. Weight of Tower & accessories.
2. Weight of wire & cables.
3. Radial thickness of ice on wires.
   - Heavy District .50 in. ice.
   - Medium " .25 " "
   - Light " .00 " "
4. Any effect of difference in elevation of supports.

TRANSVERSE

1. Horizontal wind on wires.
   - H: 8# per sq. ft. on projected area with .50 in. Ice.
   - M: 8# " " " " " " .25 " "
   - L: 12# " " " " " " .00 " "
2. Horizontal wind on Tower with no ice.
   - H: 13# per sq. ft.
   - M: 13# " " "
   - L: 19.2# " " "

   } on flat surface.

   With lattice Tower use $1\frac{1}{2}$ times projected areas of members.
3. Resultant of loads due to change in direction of conductors.

SIMULTANEOUS APPLICATION OF LOADS.*

1. When calculating transverse strength, the assumed transverse and vertical load should be taken as acting simultaneously.
2. In calculating longitudinal strength, the assumed longitudinal loads shall be taken without consideration of the vertical or transverse loads.

Table D — Allowable Unit Stresses in Steel for Transverse and Longitudinal Strengths.*

	Allowable stresses for transverse strength			Allowable stresses for longitudinal strength	
	Grade A	Grade B	Grade C	Grades A and B crossings	Grades A and B except at crossings
	Lbs. per sq. in.	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*
Structural steel:					
Tension	20,000	26,000	30,000	30,000	33,000
Compression	20,000 −80 L/R	26,000 −90 L/R	30,000 −100 L/R	30,000 −100 L/R	33,000 −100 L/R
Bolts:					
Shear	20,000	24,000	35,000	35,000	40,000
Bearing	40,000	48,000	70,000	70,000	80,000
Rivets:					
Shear	18,000	22,000	30,000	30,000	33,000
Bearing	36,000	44,000	60,000	60,000	66,000

Table E — Thickness of Steel.*

Kind of member	Thickness of main members of cross arms and legs	Thickness of other members
Galvanized:		
For localities where experience has shown deterioration of galvanized material is rapid	*Inches* 1/4	*Inches* 3/16
For other localities	3/16	1/8
Painted	1/4	*1/8

* Painted bracing members having L/R not exceeding 125 may be 3/16 inch in thickness

Table F — L/R for Compression Members *

Kind of compression member	L/R
Leg members	150
Other members having figured stresses	200
Secondary members without figured stresses	250

*Adapted from National Electrical Safety Code, U.S. Bureau of Standards.
The Author recommends these unit stresses be used only on large projects. For small projects, use A.I.S.C. stresses.

DAMS - FORCES ACTING ON

These data represent average practice and should only be used to supplement scientific analysis based on tests and on models.

PRESSURE DUE TO ICE: *Commonly assumed at from 3,000 to 5,000 lb. per sq. ft.*

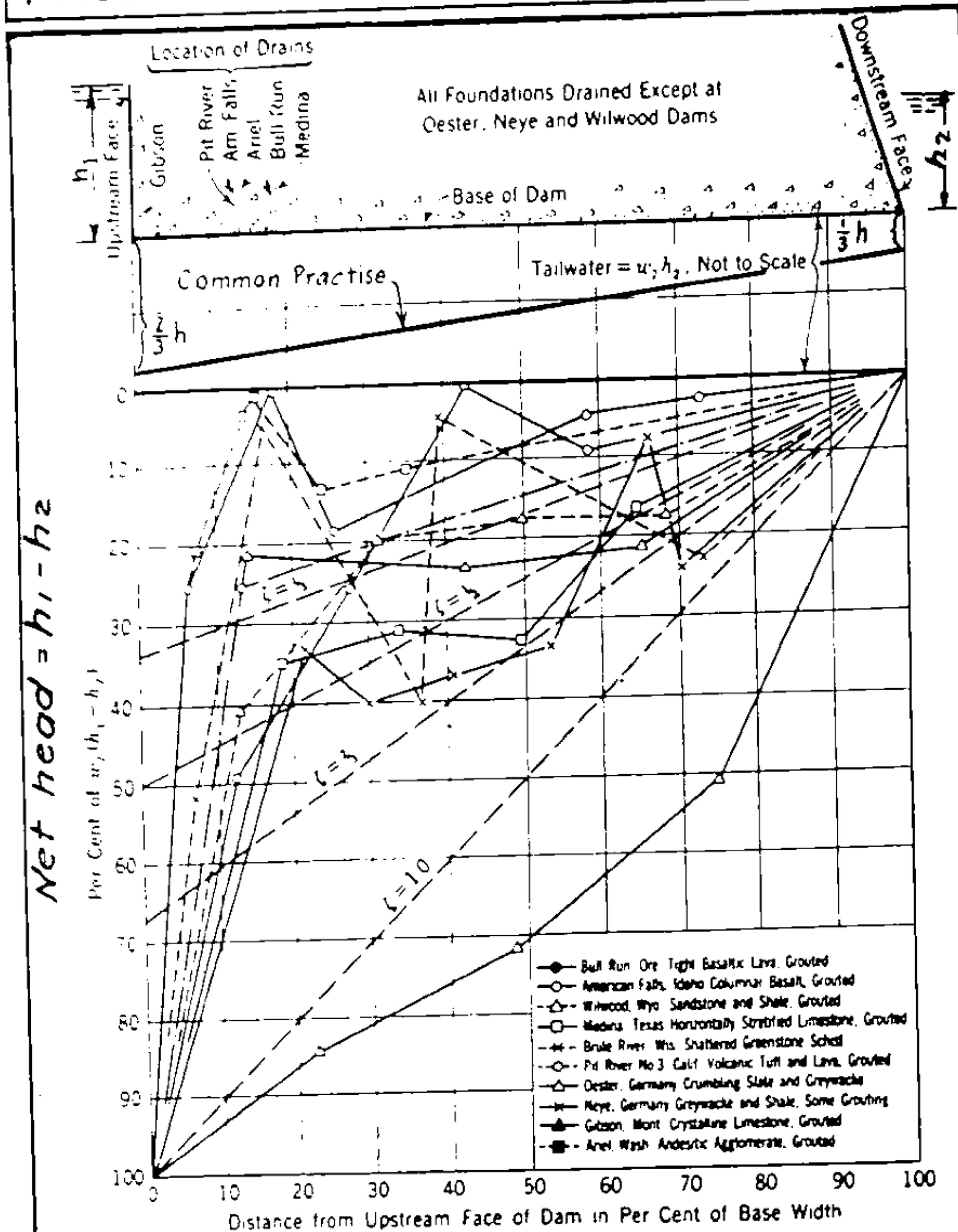
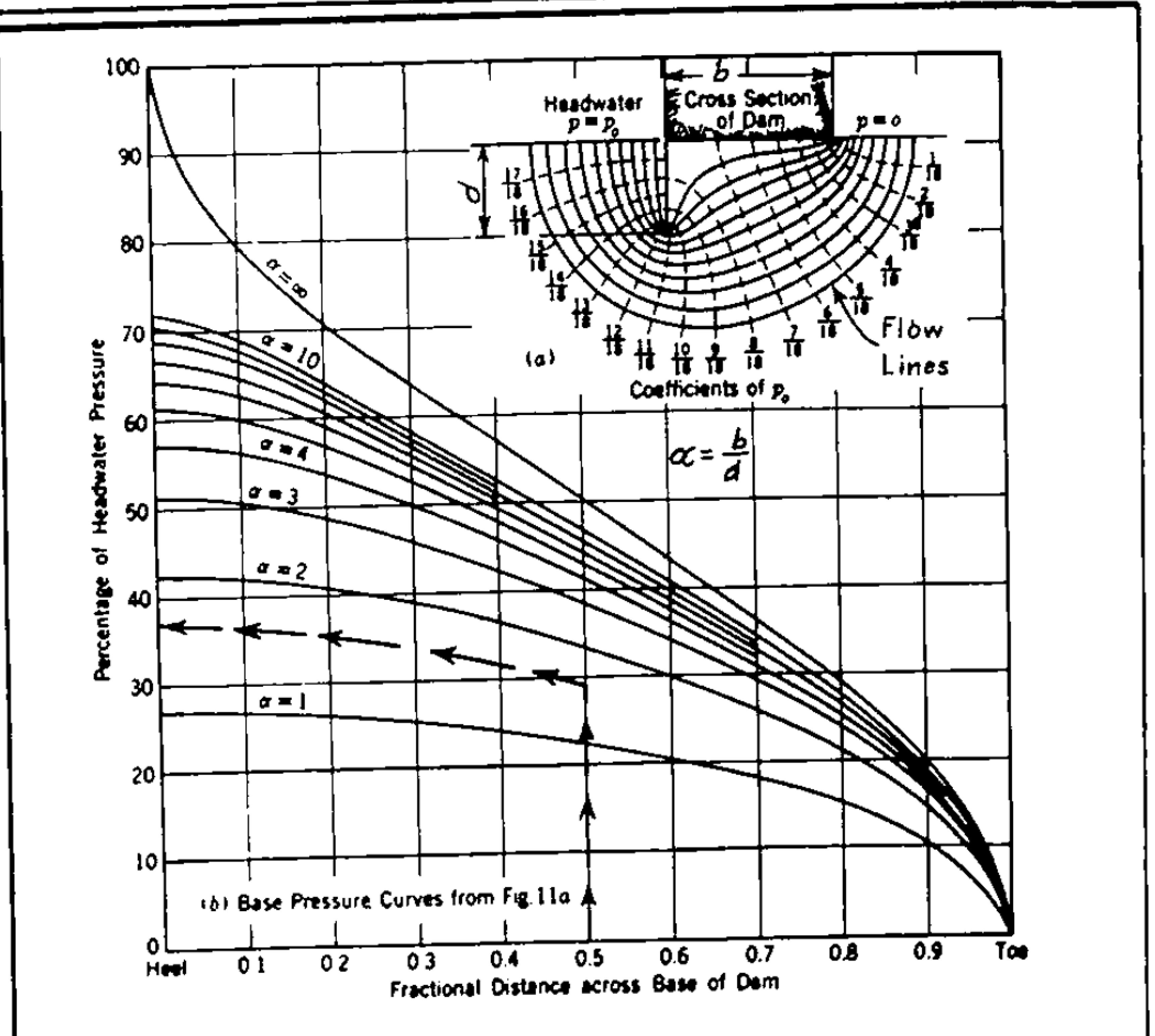


FIG. A - UPLIFT PRESSURE ACROSS BASE OF MASONRY DAM ON ROCK FOUNDATION.*



EXAMPLE:

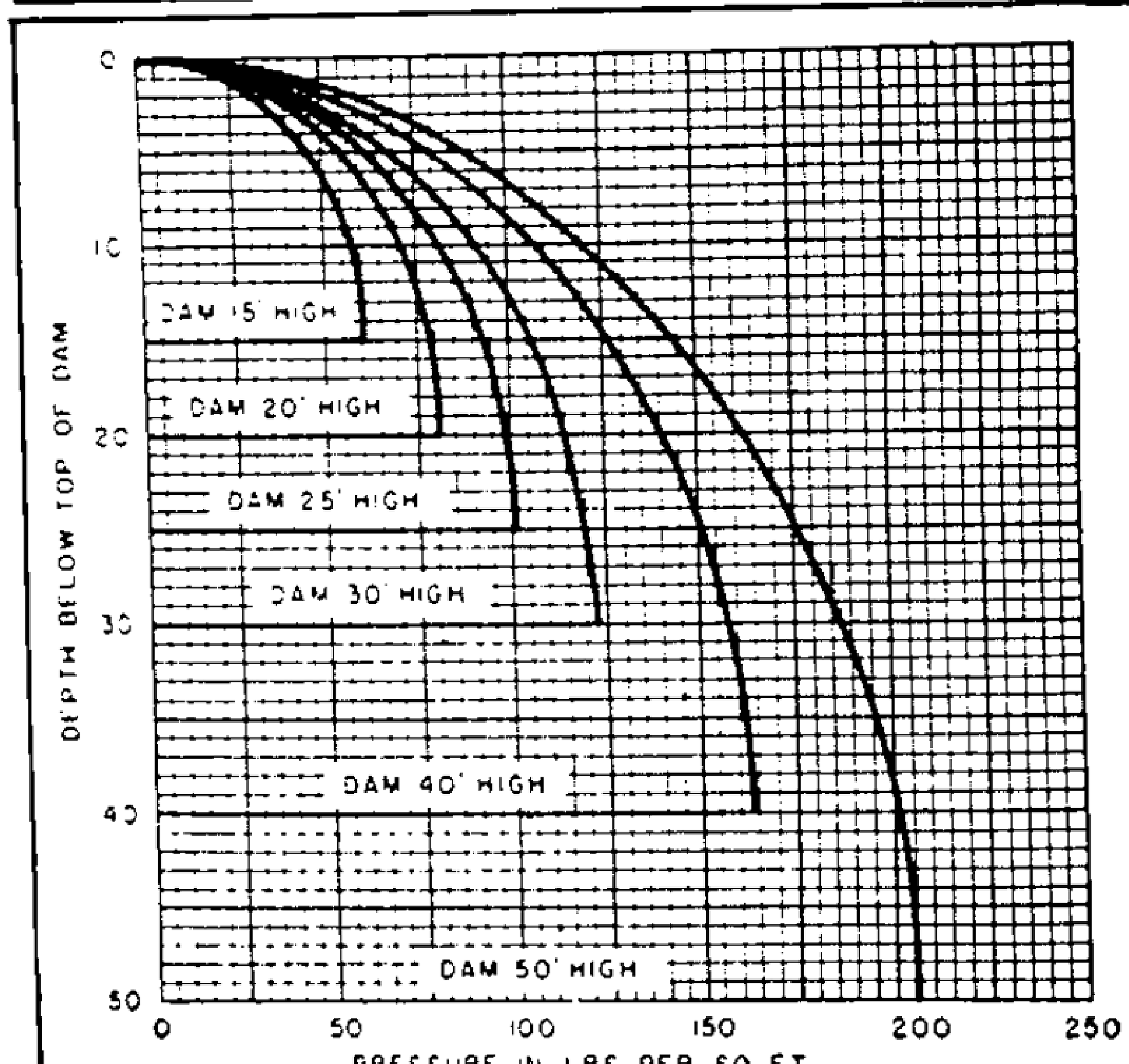
Given: Dam with: 10' base; 6' cut off; and 12' net head.

Required: To find uplift pressure at mid-point of base.

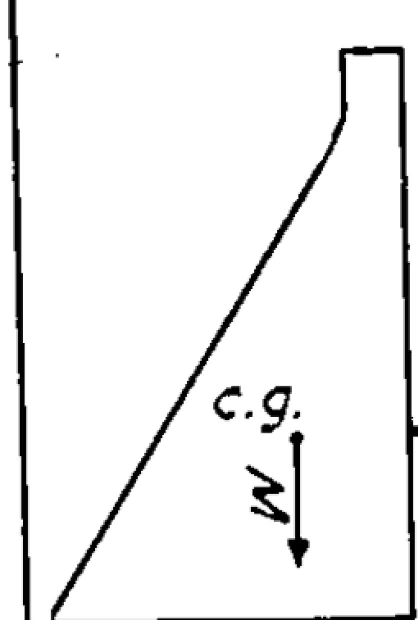
Solution: $\frac{b}{d} = \frac{10}{6} = 1.67$; from chart = 37%

$0.37 \times 12'$ head = 4.4' head.

FIG. B - UPLIFT PRESSURE ACROSS BASE OF MASONRY DAM ON EARTH FOUNDATION.**



EARTHQUAKE PRESSURES
APPROXIMATE PRESSURES FROM AN EARTHQUAKE OF AMPLITUDE = 0.1G. AND PERIOD = 1 SEC.



FORMULA:

$$He = \frac{0.1W}{g}$$

NOTATION:

He = Longitudinal overturning force applied at c.g.

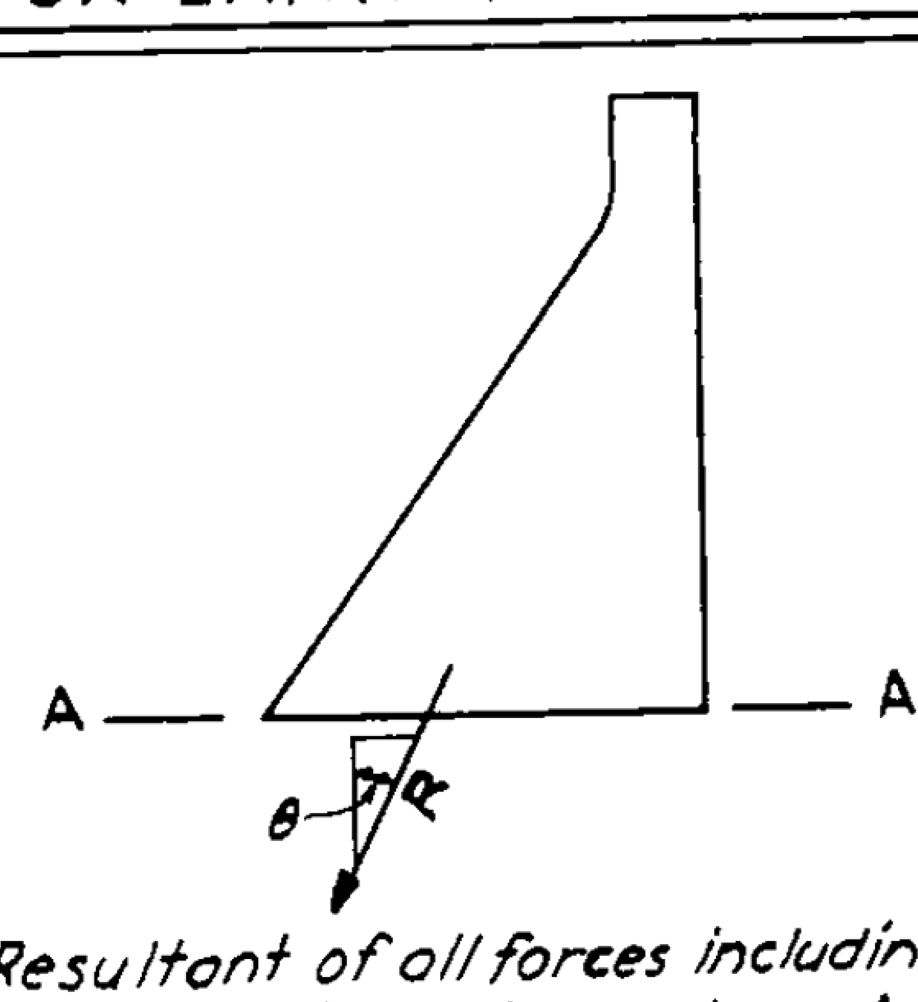
W = Weight of dam.

g = 32.2.

NOTE: Avoid location across a fault line.

Other factors are: Water pressure due to shock, relations between period of vibration of the foundation and of the structure. As these approach each other, there is danger of resonance.

FIG. C - FORCES CAUSED BY EARTHQUAKES.***



R = Resultant of all forces including uplift acting above plane A-A.

Keep "R" within middle third of base in all cases.

Keep tan θ < 0.75

Maximum inclined pressure 60,000 lb. per sq. ft. or less depending on nature of rock.

FIG. D - RESISTANCE TO SLIDING - FOR ROCK.

*Ivan E. Hoak, Civil Eng. 1932. **L. F. Harga, Trans. A.S.C.E. 1935 *** From Low Dams by National Resources Comm.

DAMS- RESULTANT PRESSURE-PRACTICAL SECTION

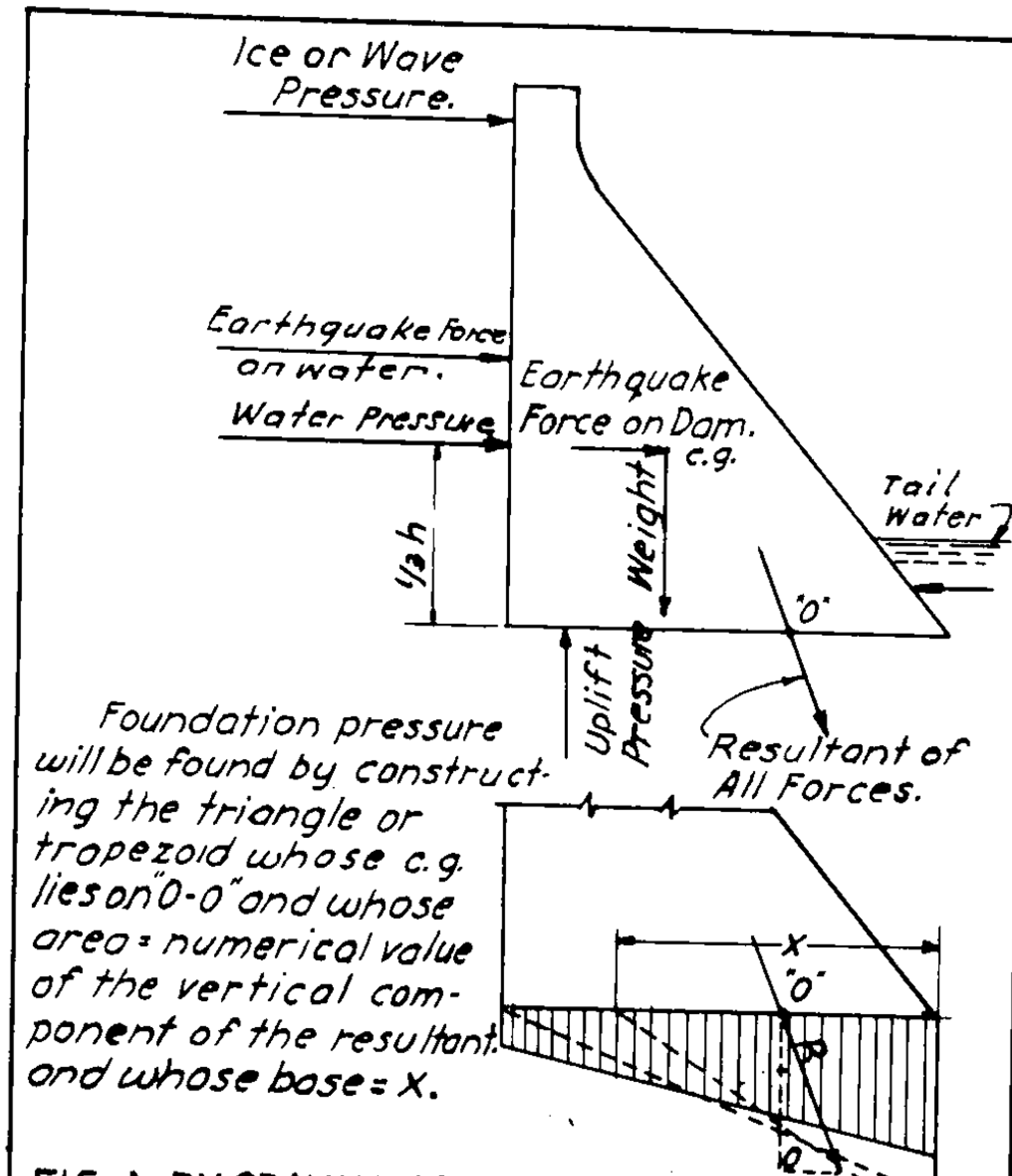
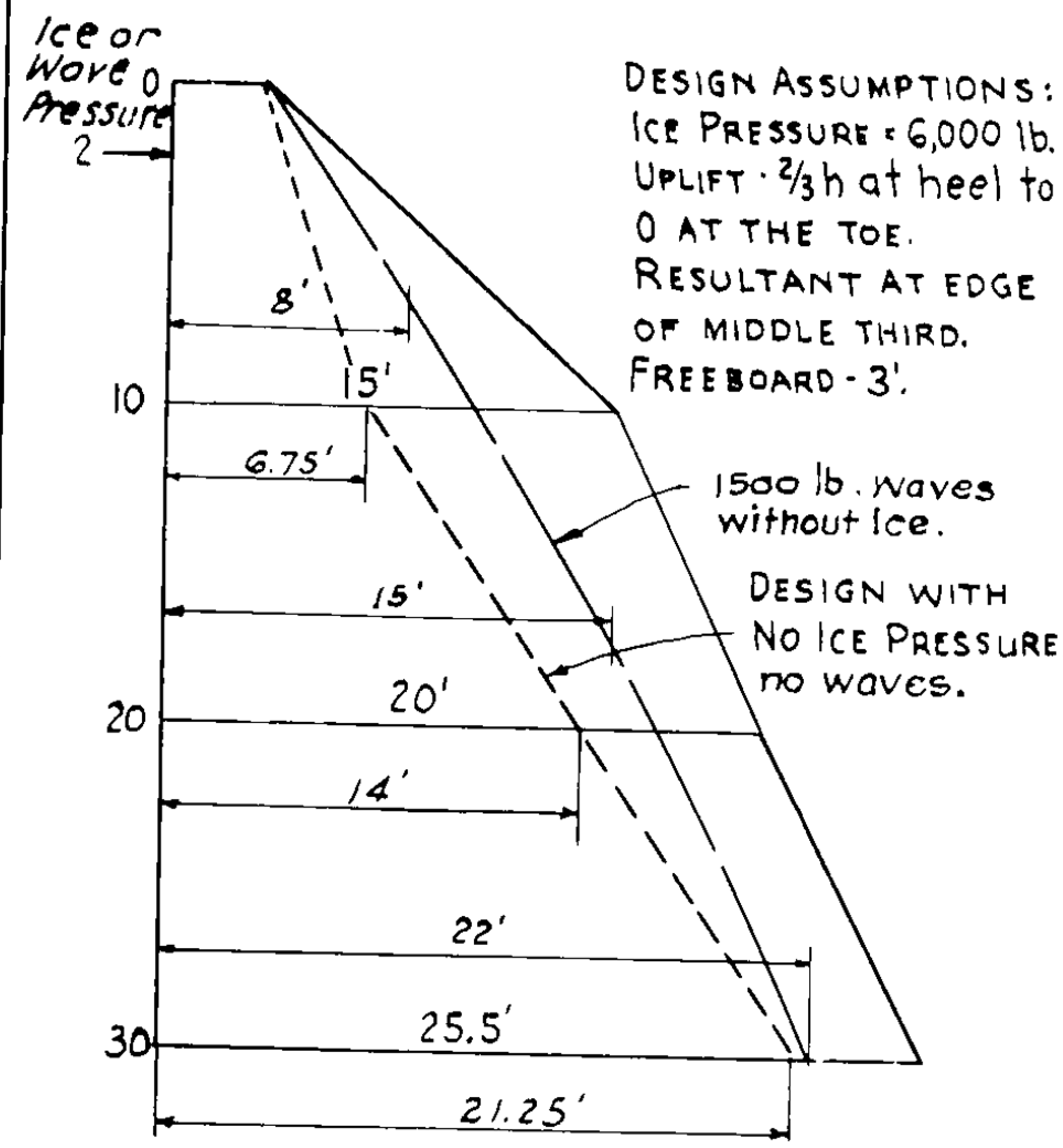
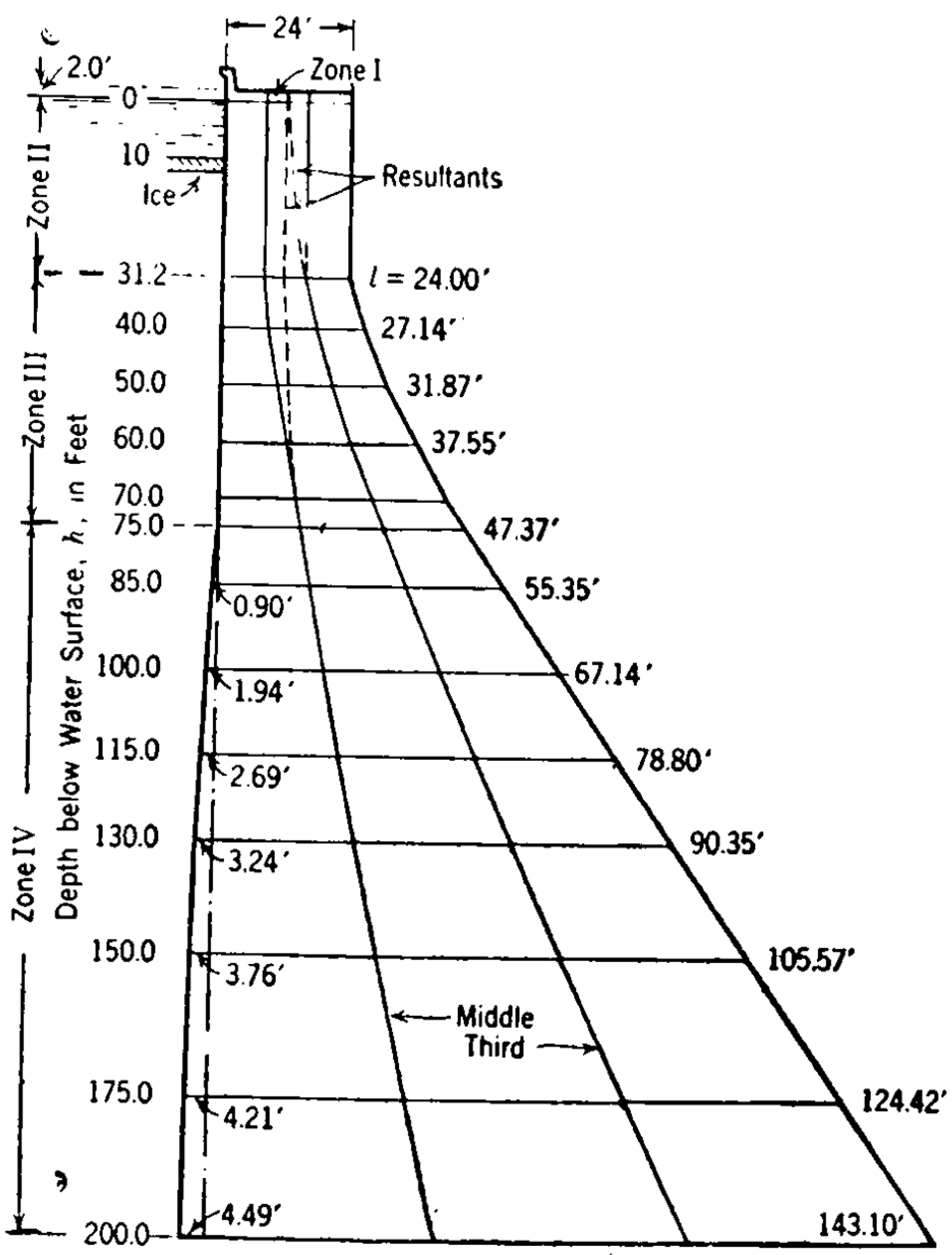


FIG. A-DIAGRAMMATIC REPRESENTATION OF PROCESS OF DETERMINING FOUNDATION PRESSURES ON A MASONRY DAM.



DESIGN ASSUMPTIONS:-
ICE PRESSURE = 6,000 lb.
UPLIFT · 2/3 h at heel to 0 AT THE TOE.
RESULTANT AT EDGE OF MIDDLE THIRD.
FREEBOARD - 3'.

FIG. B- PRACTICAL SECTION FOR CONCRETE DAMS TO 30' HIGH.



DESIGN ASSUMPTIONS:

Maximum Inclined Compressive Stress is 60,000 lb./sq. ft.
Maximum Friction Factor = 0.75
Maximum Uplift Pressure = 0.5 height of water.
Uplift Area - Across full base width.
Wind Velocity = 80 miles per hour.
Ice Pressure = 9,000 lb./lin. ft.
Fetch = 4 miles.

FIG. C- PRACTICAL CONCRETE DAM SECTION.*

*Adapted from Engineering for Dams by Creager, Justin & Hinds.

DAMS - EARTH DAM SECTIONS

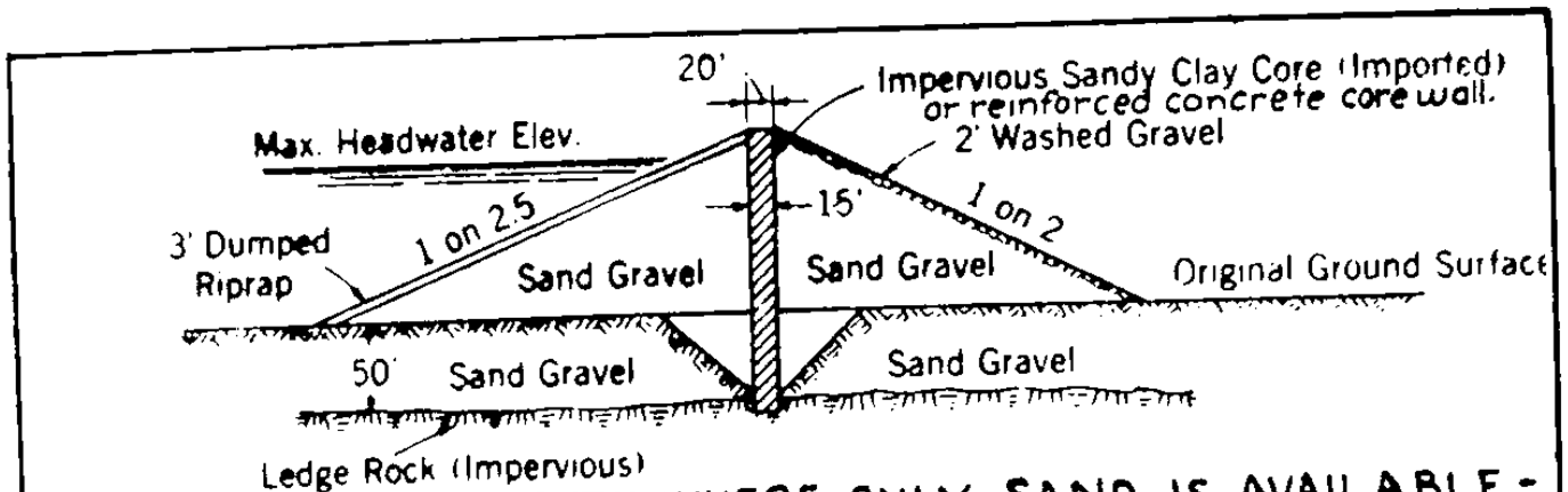


FIG. A - DESIGN FOR SITE WHERE ONLY SAND IS AVAILABLE - FOUNDATION IS PERVIOUS FOR 50 FOOT DEPTH.*

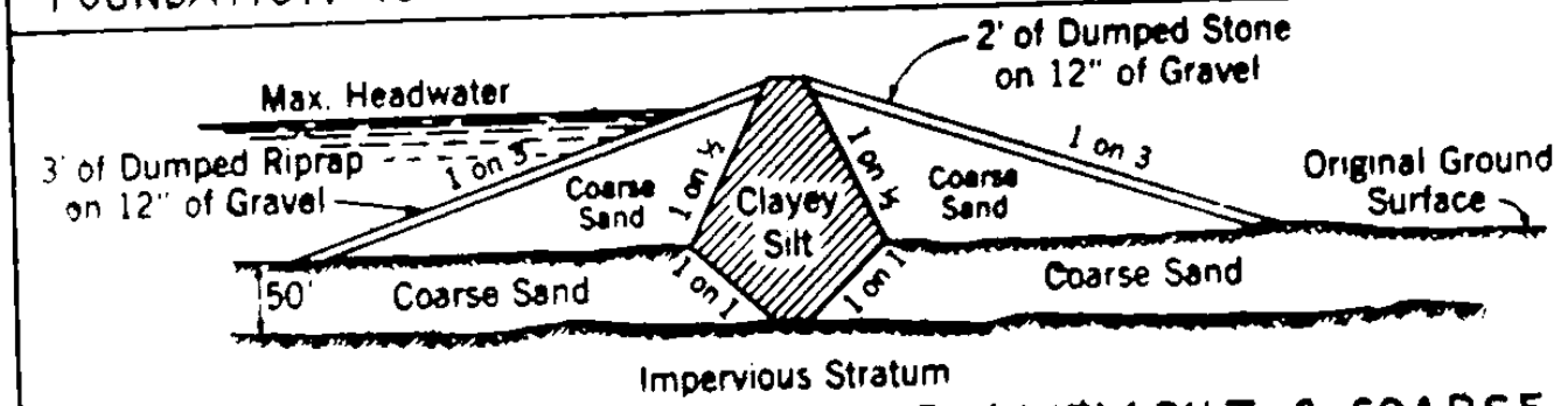


FIG. B. - DESIGN FOR SITE WHERE CLAYEY SILT & COARSE SAND ARE AVAILABLE - FOUNDATION SAME AS FOR FIG. A.*

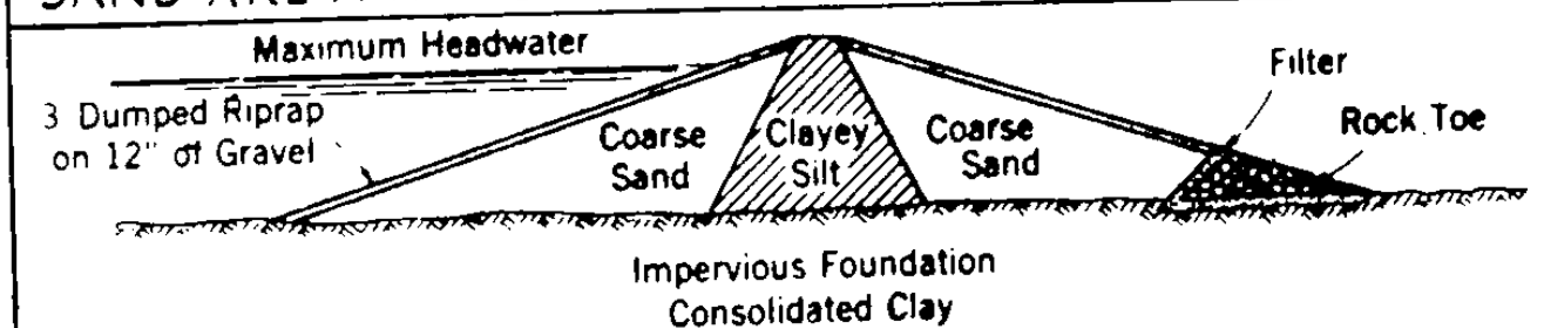


FIG. C - DESIGN FOR SITE WHERE CLAYEY SILT & COARSE SAND ARE AVAILABLE - FOUNDATION IS IMPERVIOUS MATERIAL.*

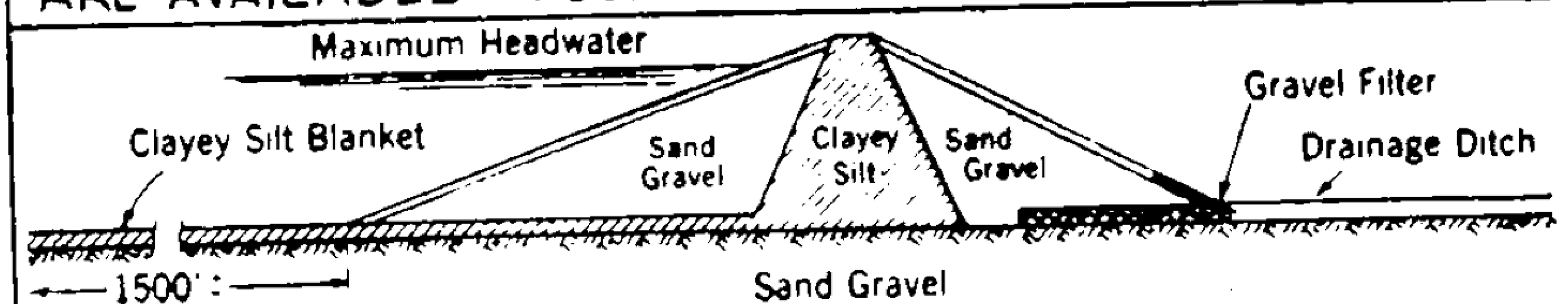


FIG. D - DESIGN FOR SITE WHERE CLAYEY SILT & COARSE SAND ARE AVAILABLE - FOUNDATION PERVIOUS TO GREAT DEPTH.*

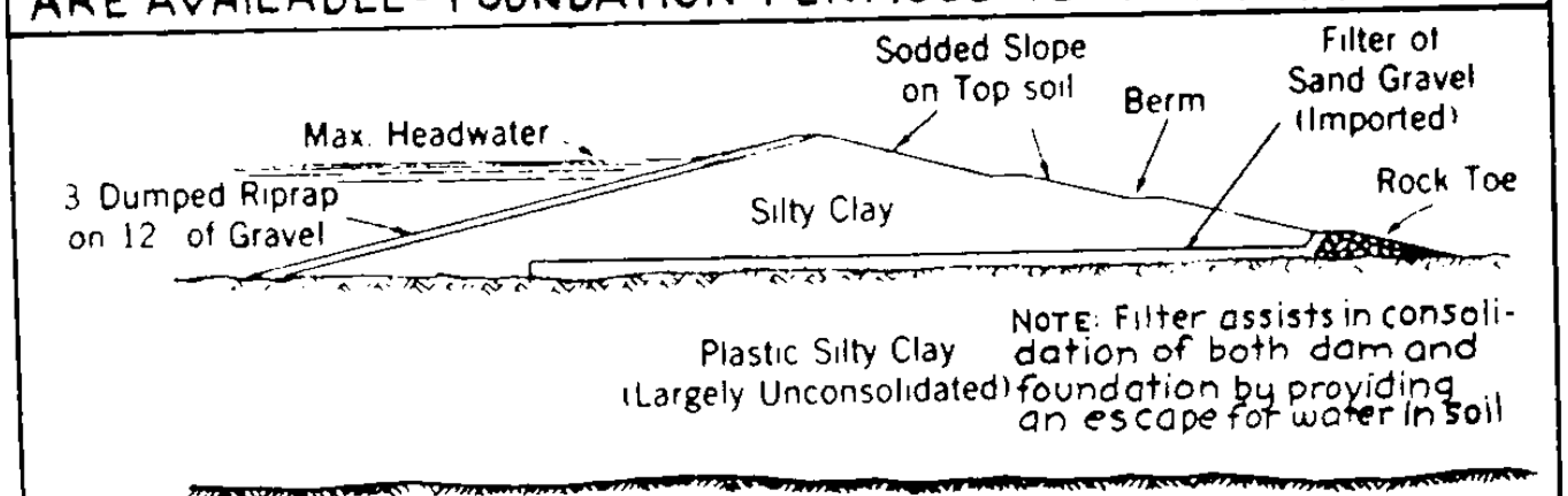


FIG. E - DESIGN FOR SITE WHERE ONLY SILTY CLAY IS AVAILABLE - FOUNDATION IS UNCONSOLIDATED SILTY CLAY (PLASTIC).*

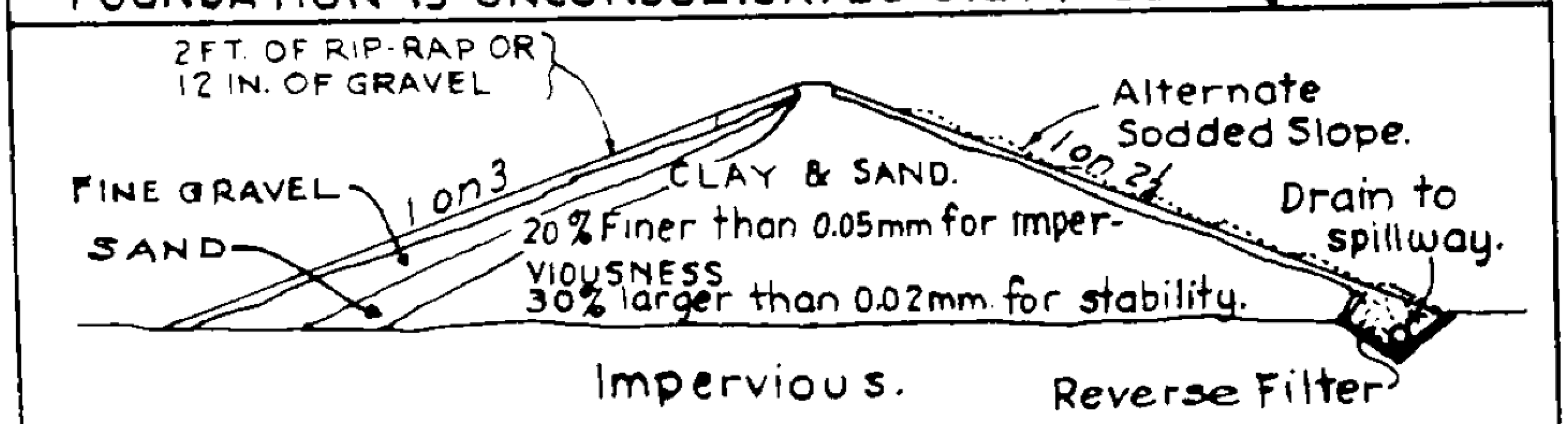


FIG. F - DESIGN FOR SITE WHERE CLAY & SAND ARE AVAILABLE. FOUNDATION REASONABLY IMPERVIOUS.†

See Pg. 3-20 to 3-25 for additional data.

REMARKS ON SECTIONS.

Compaction should be made to maximum density at optimum moisture.

Impervious sections and coarse sections should be within the limits given in Fig. A, Pg. 4-74.

Shear across dam sections should be checked by scientific investigation, but the sections shown should give adequate safety factor for the materials noted.

Earth dams require separate overflow structures, as water overtopping dam will destroy it.

Foundations should never be on peat or vegetable loam.

Compact in 6" layers with power equipment and sheepsfoot rollers.

Sheepsfoot rollers should be used to reduce moisture and aid compaction.

Rip-rap with fine gravel & sand on upstream surface to protect against wave action and provide a reverse filter in case of sudden drawdown.

Coarse sand - 85% size >0.8mm.

Check soft foundation assumptions by Elastic Theory, Pg. 3-22.

*Adapted from Engineering for Dams by Justin, Hinds & Creager., † by Author.

DAMS - TYPICAL SECTIONS

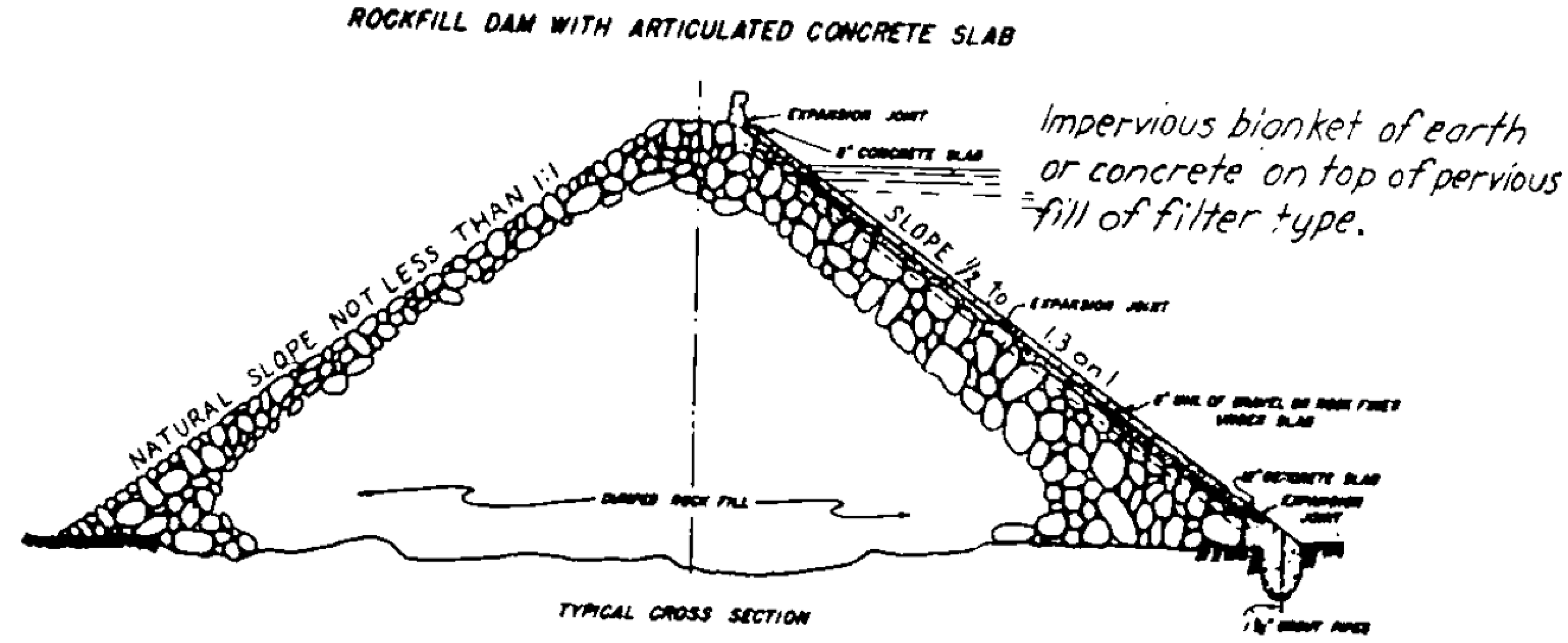


FIG. A - ROCK FILL DAMS.*

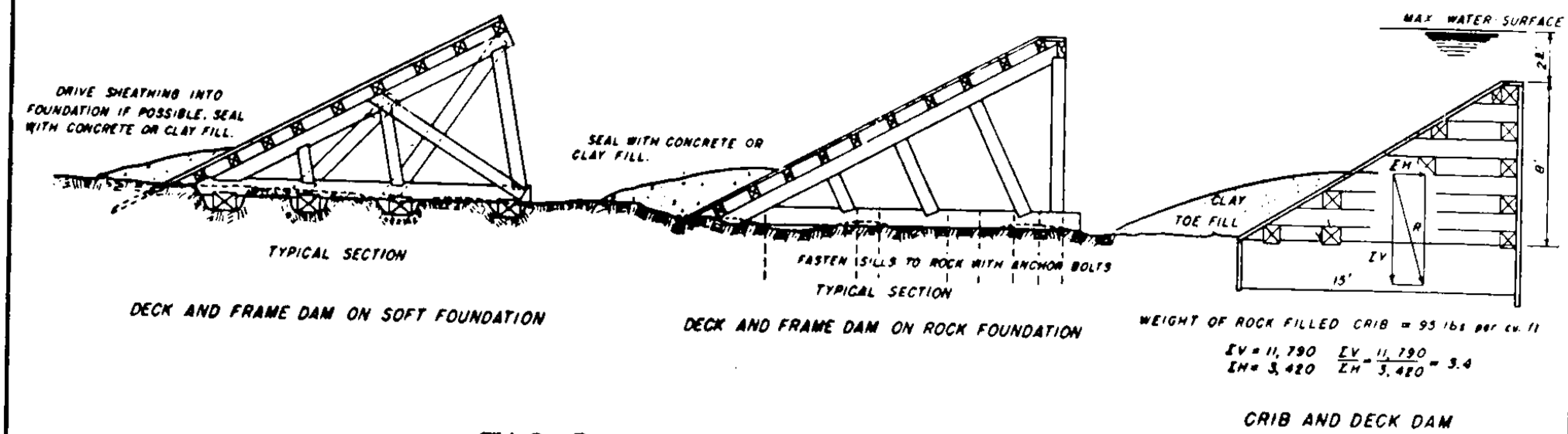


FIG. B - LOG CRIB DAMS.*

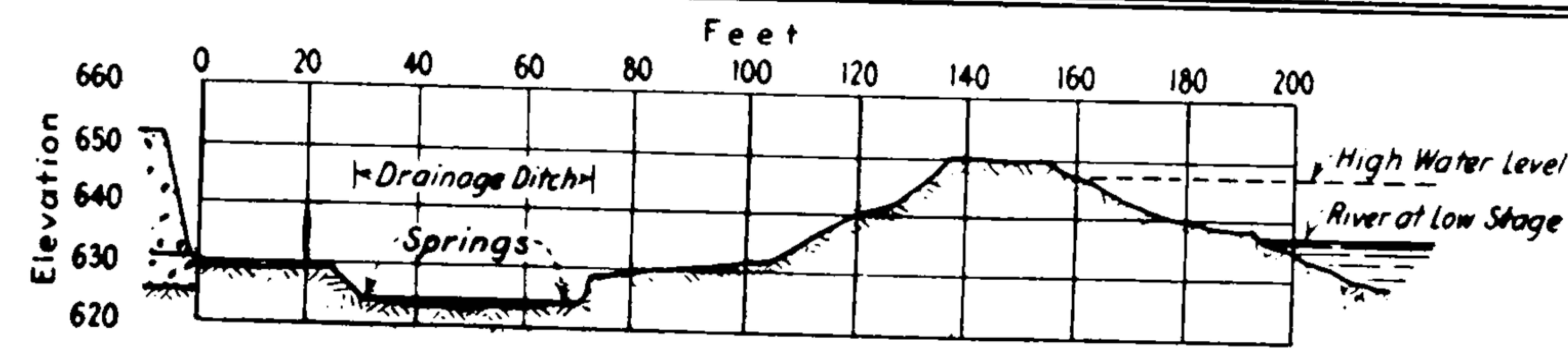


FIG. C - EARTH DIKE (for cofferdam).**

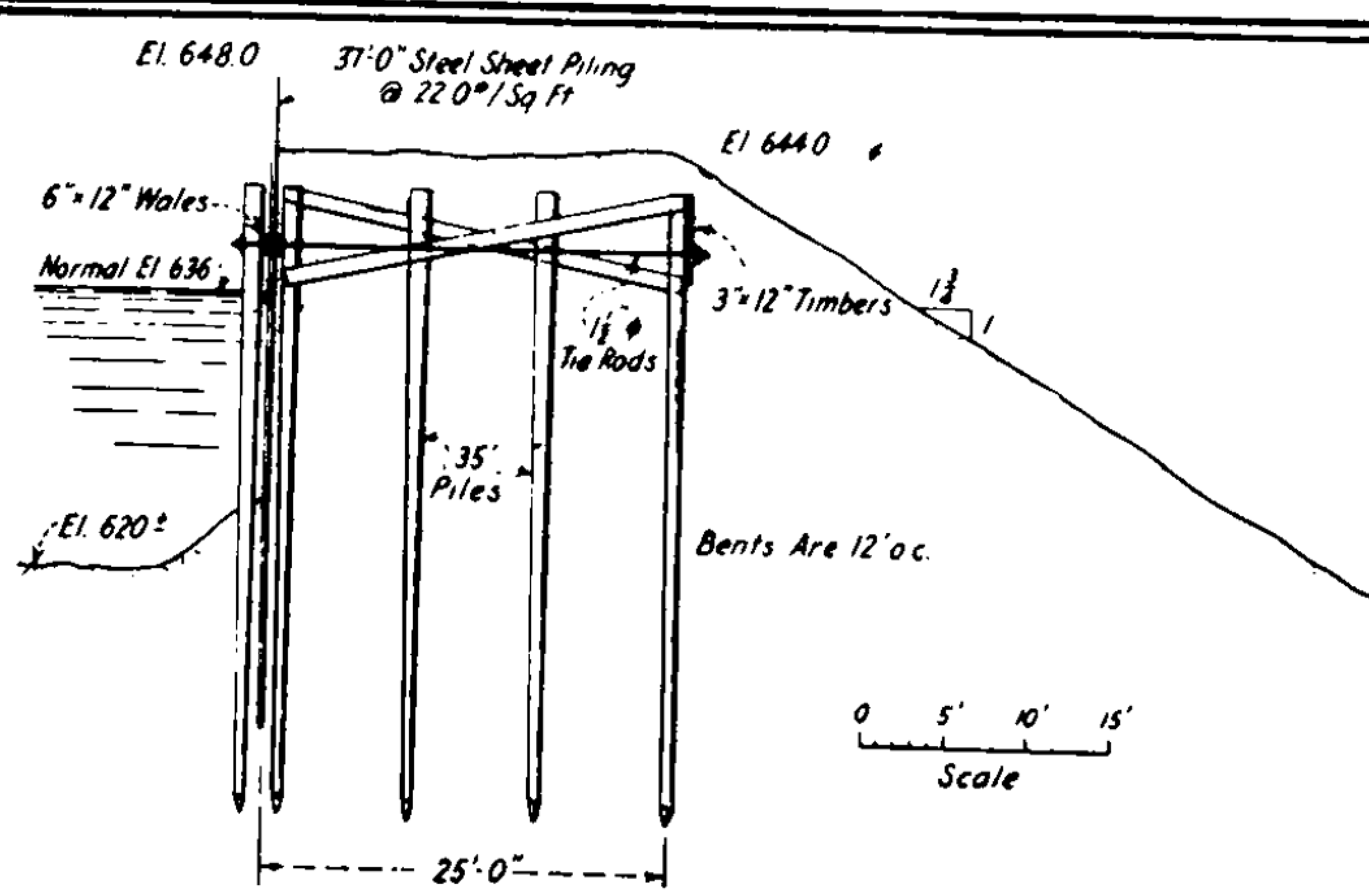


FIG. D - TYPICAL COFFERDAM.**

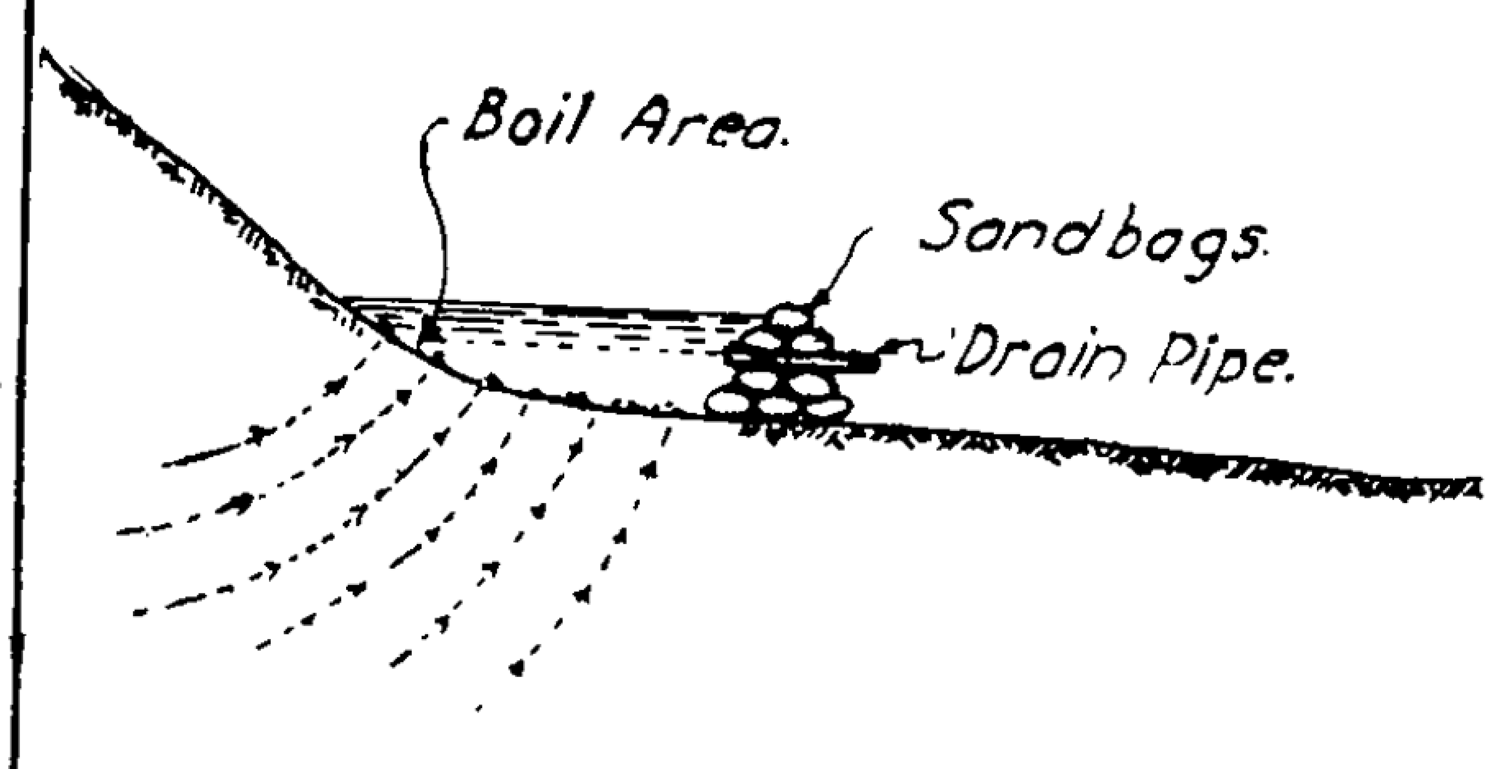
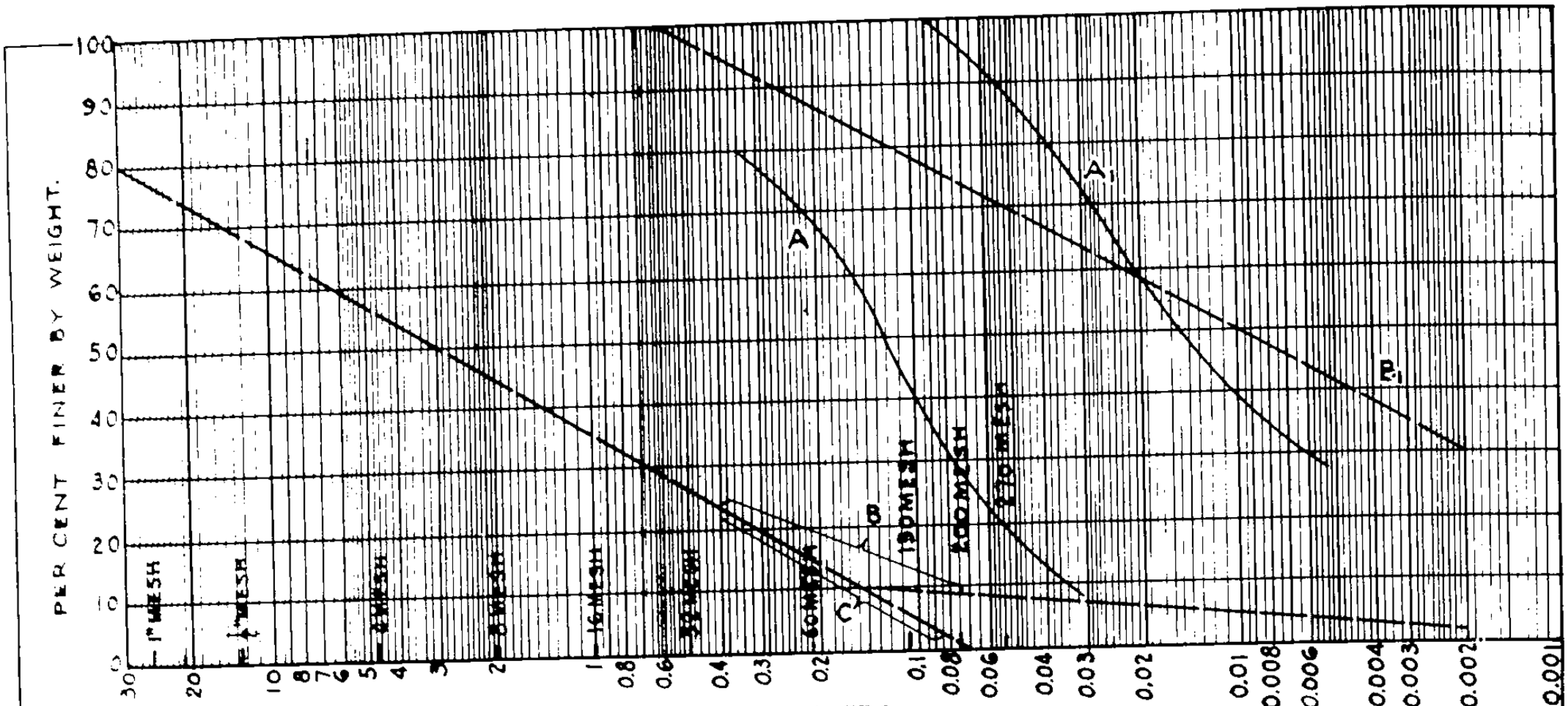


FIG. E - CORRECTION OF A BOIL.**

*Adopted from Low Dams by National Resources Comm.
** Adopted from White & Prentis, Cofferdams, by permission of Columbia University Press.

DAMS - MISCELLANEOUS CRITERIA



A. Possible upper limit of satisfactory core material.

A_1. Probable upper limit of safe core material (Urquhart).

B-B_1. Proposed limits for ungraded materials suitable for impervious section for rolled fill dams (Lee)

C-B. Approximate limit of materials for impervious sections of rolled fill dams (Justin).

FIG. A - CHART FOR SELECTION OF MATERIALS.* See also Pg. 3-05.

TABLE B - SETTLEMENT EXPECTANCY.+

Material	Pressure (in Tons/Sq.Ft.). No Measurable Settlement.	Detrimental Settlement.
Stiff Clay	2.0	4.4
Silt	1.5	1.6
Sand-Clay	2.4	1.6
Fine Sand	2.0	1.8
	Note inconsistency.	

Rigid Structures: Provide for settlement, shrinkage, and expansion by use of joints and keyways.

Flexible Structures: Allow time for foundation settlement. Allow for consolidation in completing fill.

Basis For Computing Settlement.

$$\text{Settlement} = \frac{e_1 - e_2}{1 + e_1} \times h.$$

Where:

e_1 = Void ratio before consolidation.

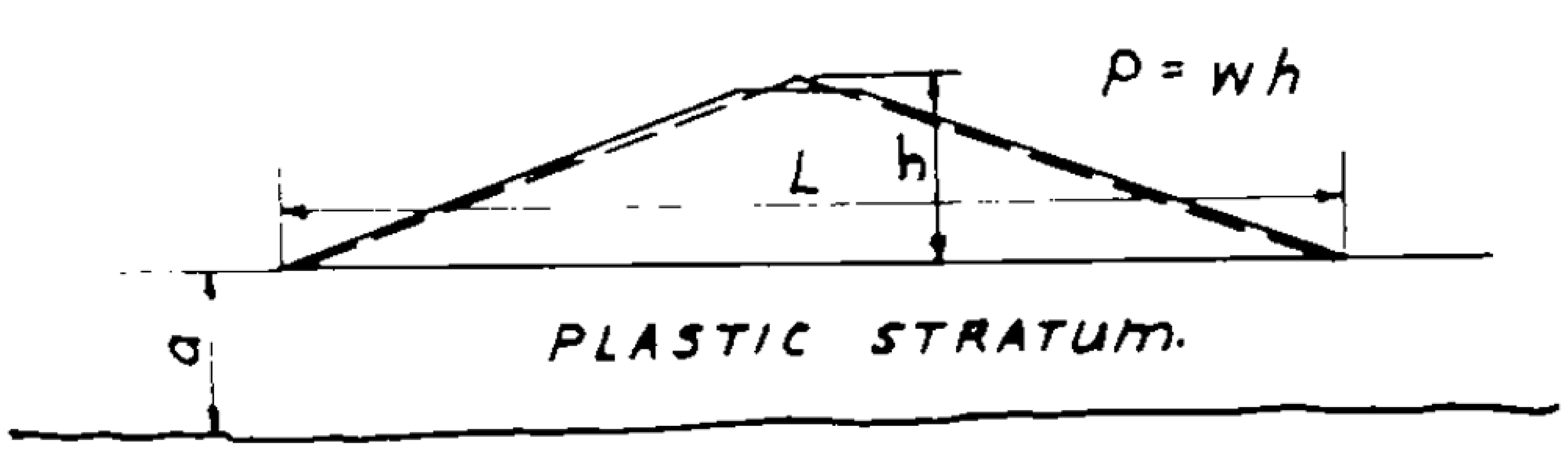
e_2 = " " after "

h = Thickness of layer in feet.

FOUNDATION PRESSURES FOR EARTH DAMS.

For bearing capacities of soils & rocks see p. 2-50.

Soft formations should be checked for shear as shown below.



$$S = \frac{P \times a}{L}$$ (Applies only to plastic soils). ⊕

Assumes equivalent △ cross-section.

S = Maximum unit shear - lb. per sq. in.

P = Maximum unit pressure - lb. per sq. in.

For very approx. limits for S see Table D.

FIG. C - FOUNDATIONS OF PLASTIC MATERIAL.

TABLE D - SOIL SHEAR VALUES.

Soil.	Cohesion Per Sq. Ft.	Angle of Internal Friction ϕ
Clay - Liquid. **	100	0°
" - Very Soft **	200	2°
" - Soft **	400	4°
" - Fairly Stiff **	1,000	6°
" - Very Stiff **	2,000	12°
Sand - Wet **	0	10°
" - Dry or Unmoved **	0	34°
Silt. ***	0	20°±
Cemented Sand & Gravel - Wet **	500	34°
" " " " - Dry **	1000	34°

Shear Strength = Cohesion + W tan ϕ. Apply a safety factor of 2. Actual determination from soil analysis is advisable.

*From Low Dams by National Resources Comm. + From Transactions of A.S.C.E.

⊕ From The Application of Theories of Elasticity and Plasticity to Foundation Problems by Leo Jurgenson, J. Boston Soc. C. Es. July 1934. ** Adapted from Hogentogler, Engineering Properties of Soils, McGraw-Hill, Based on quick shear test. *** By author.

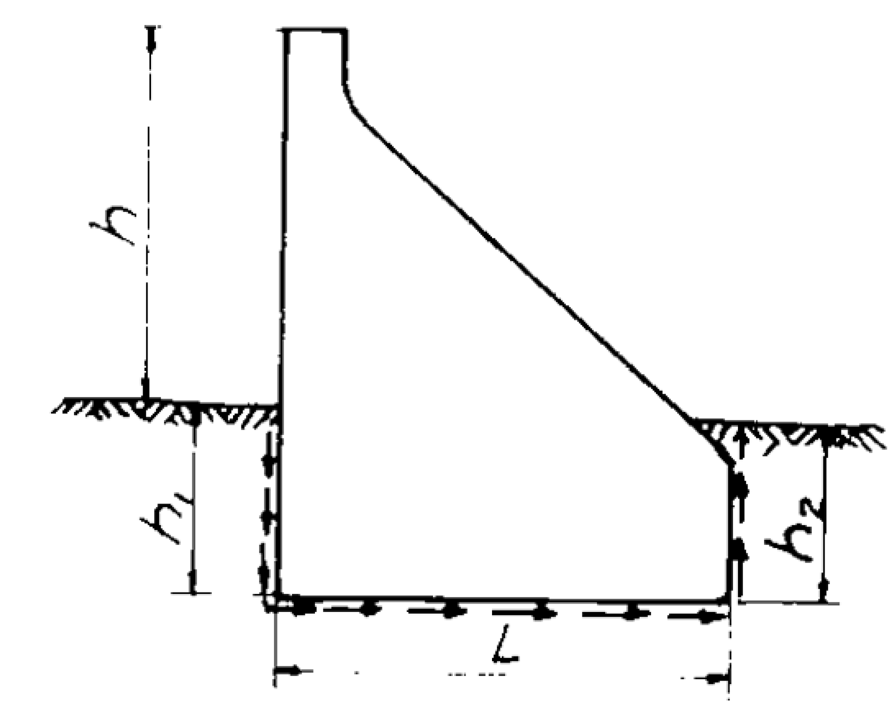
DAMS - MISCELLANEOUS REQUIREMENTS - 1

SEEPAGE DATA: *The flow of water from the upstream side of dam to the downstream side, through the embankment of earth dams and along the line of creep, must be kept within safe limits in respect to volume and velocity to prevent piping & boiling.*

Creep = Path of water along contact surface between structure and foundation.

TABLE A - RECOMMENDED CREEP RATIOS,* R (After Lane).

MATERIAL	R	MATERIAL	R
Very Fine Sand & Silt.	8.5	Boulders with some Cobbles and Gravel.	2.5
Fine Sand	7.0	Soft Clay	3.0
Medium Sand	6.0	Medium Clay	2.0
Coarse Sand	5.0	Hard Clay	1.8
Fine Gravel	4.0	Very Hard Clay or Hardpan.	1.6
Medium Gravel	3.5		
Coarse Gravel including some Cobbles.	3.0		



$$R = \frac{h_1 + h_2 + \frac{1}{3}L}{h}$$

R = Creep Ratio.
(A check against piping).

NOTE: If "R" for a critical section is less than the tabular value, additional flow resistance should be inserted in design section.

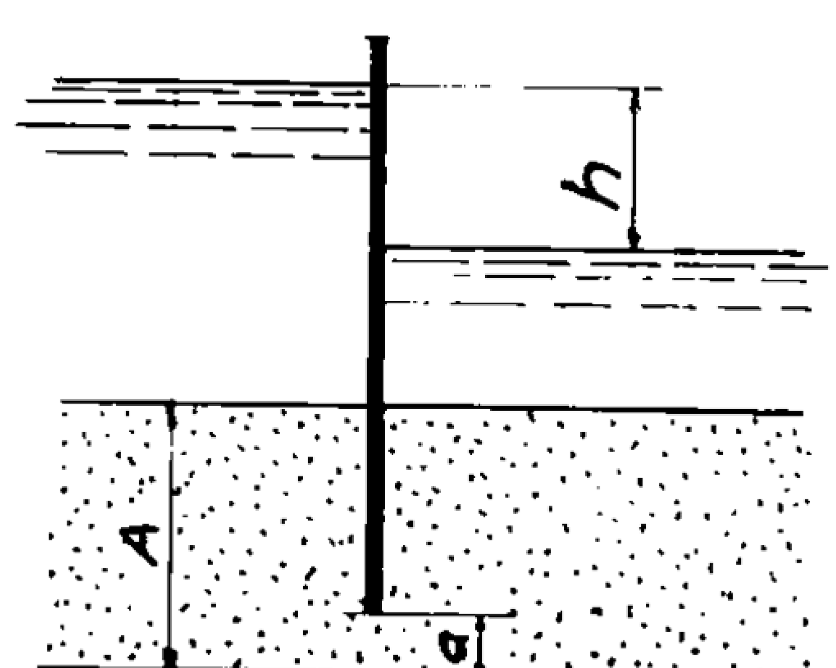
Limitations: Does not take into account -

1. Importance of shape - see Fig. C & D p. 4-78.
2. Line of creep may not be most direct path of seepage.

TABLE B - SEEPAGE LOSSES FROM COFFERDAMS.**

RATIO OF AREAS a/A	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
ϕ	0.49	0.62	0.74	0.86	1.00	1.16	1.35	1.62	2.06

MATERIAL	K
Clean Gravel	0.2662 - 0.02778
Clean Sand	$5787 \times 10^{-7} - 5787 \times 10^{-9}$
Fine Sand or Silt	$2778 \times 10^{-9} - 2778 \times 10^{-12}$
Clay.	Less than $- 2778 \times 10^{-12}$



SCHOKLITSCH FORMULA.

$$Q = 100 K \phi \frac{h}{2}$$

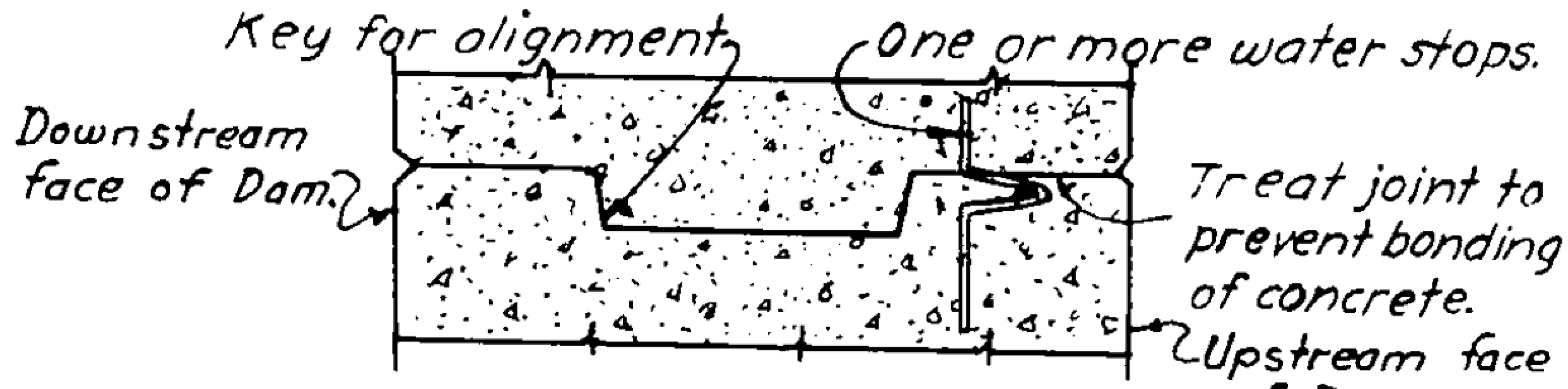
Where: Q = Quantity of flow in cu.ft./sec.
K = Coefficient of permeability in cu.ft./sec. - See Table B, but a soil analysis is indicated.
ϕ = Value in Table B above.

Alternate Formula: †

$$Q_1 = C L h$$

Where:-
Q_1 = Flow in gal. per min.
C = 1.25 x effective (or 10%) grain size of sand. See p. 3-01 for visual determination of grain size.
h = Head loss in feet.
L = Length of dam in feet.

NOTE: On dams over 15' high, seepage losses through embankments should be determined by experiments on scale models.



HORIZONTAL SECTION.

Allow lapse of time between concreting adjoining sections to reduce shrinkage.

FIG. C - CONSTRUCTION JOINT ESSENTIALS.

FLOTATION GRADIENT. †

Hydraulic Gradient at which boils or piping occur.

Flotation Gradient = F_c

$$F_c = \frac{H}{L} = (1-P)(S-1)$$

F_c = 1 approximately.
P = Proportion of voids.
S = Specific gravity of sand grains.
H = Hydraulic head.
L = Thickness of bed.

*Adapted from Transactions of A.S.C.E. - 1935, pg. 1235 by E.W. Lane. ** From Low Dams by National Resources Comm. † Adapted from White & Prentis, Cofferdams, by permission of Columbia University Press.

DAMS - MISCELLANEOUS REQUIREMENTS-2

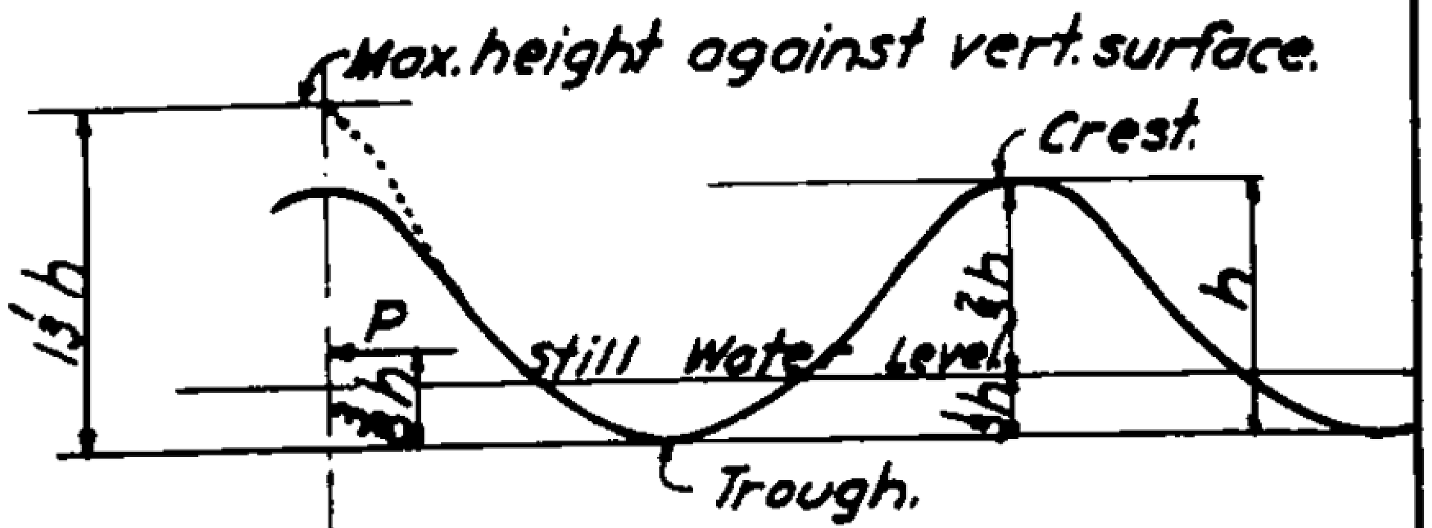
STEVENSON FORMULA:

For "F" greater than 20 miles:

$$h = 0.17\sqrt{VF}$$

For "F" less than 20 miles:

$$h = 0.17\sqrt{VF} + 2.5 - F^{\frac{1}{4}}$$



Where: h = Height of wave in feet.
V = Wind velocity in miles per hour.
F = Unobstructed length of lake in statute miles (fetch).

Wave Pressure, $P = 125h^2$ in pounds per linear foot.

Maximum height of waves: On a vertical surface = $1.33h$.
On an inclined surface = $1.5h$.

Minimum Freeboard on lakes less than 2 miles long = 2 feet.

FIG. A - HEIGHT OF FREEBOARD WAVE ACTION.*

NOTE: Waves exert scouring action as they travel up and down slopes. Embankment should be protected by paving, rip-rap, etc.; provision for drainage, in case of rapid drawdown of reservoir, should be made.

ZUIDER ZEE FORMULA:

$$S = \frac{V^2 F}{1400d} \times \cos A$$

Where: S = Rise of water level above normal in feet.
V = Wind velocity in miles per hour.
F = Unobstructed length of lake in miles (fetch).
d = Average depth of water in feet.
A = Angle between fetch and direction of wind.

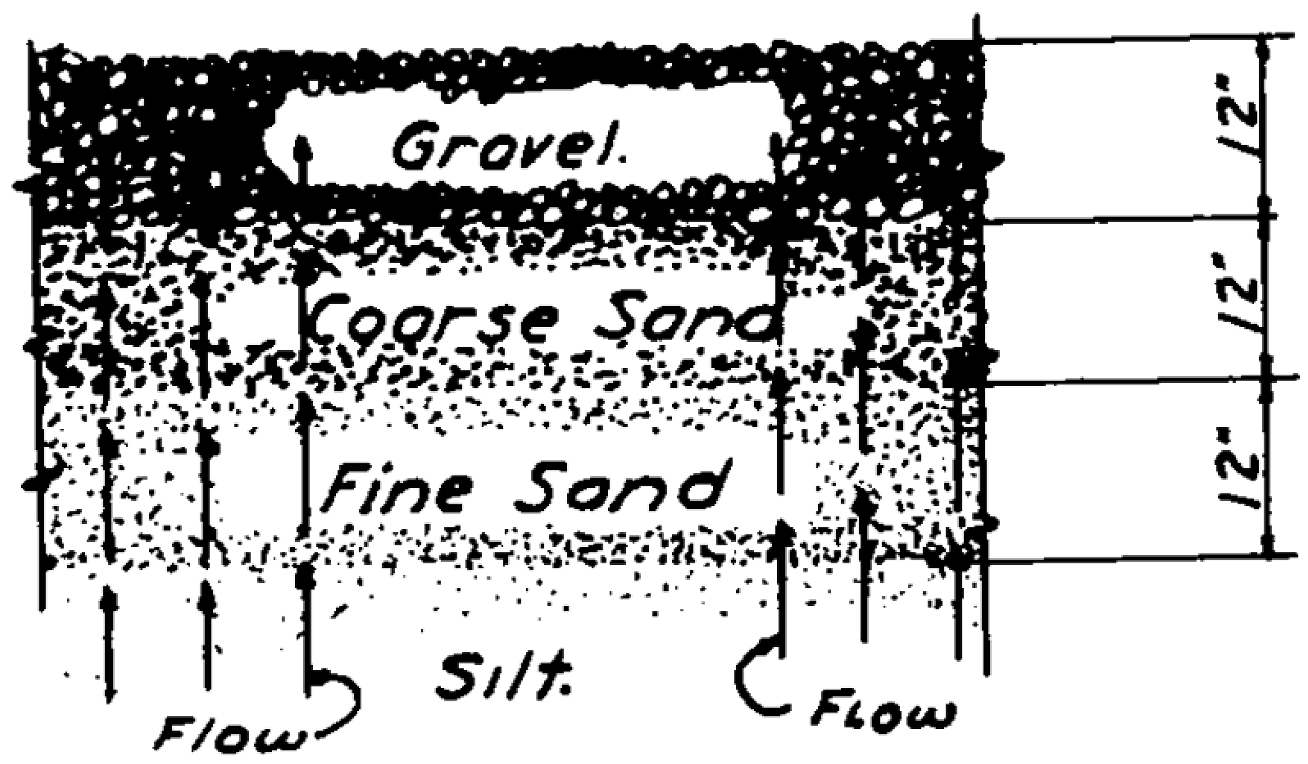
FIG. B - RISE IN WATER LEVEL DUE TO WIND.

Rule for filter material is based on 15% size.

15% size means 15% by weight of particles are smaller than size given and 85% are larger.

To determine required size - step up grain size by 9.

Layers of material should be 12" min. thickness.



Example:

Given Silt whose grain size	= 0.01 mm.	Based on 15% size.
First layer - fine sand	= 0.09 mm.	
Second layer - coarse sand	= 0.81 mm.	
Third layer - gravel	= 7.3 mm.	

See also ratio of 15% to 85% sizes, see Pg. 3-18.

FIG. C - SELECTION OF MATERIAL FOR REVERSE FILTER.

*Adopted from Transactions A.S.C.E., 1935, pg. 984 by D.A. Molitor.

DAMS - OUTLET STRUCTURES

SPILLWAY DESIGN

Spillways must have sufficient capacity that dam will never be overtopped. Compute storm peak run off - (a) See pages 5-00 to 5-02; (b) Check with high-water history of stream; (c) In addition make a hydrographic study. Use a liberal factor of safety.

FORMULA FOR DESIGN OF SPILLWAY OVERFLOW CAPACITY.

$$Q = L C H^{3/2}$$

Where:

- Q = Discharge in cubic ft. per sec.
- L = Length of crest in feet.
- C = Coefficient - See Table A.
- H = Head on crest in feet.

TABLE A - DISCHARGE COEFFICIENTS FOR FIG B. *

Nº IN FIG. B	HEAD IN FEET.									
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
1	3.32	3.44	3.46	3.42	3.41	3.46	3.50			
2	3.22	3.48	3.61	3.67	3.70	3.72				
3	3.15	3.45	3.64	3.75	3.82	3.87	3.88			
4	3.23	3.34	3.43	3.52	3.59	3.64				
5	3.18	3.30	3.37	3.42	3.46	3.49	3.52	3.54		
6	3.28	3.50	3.54	3.52	3.36	3.31	3.30			
7	3.53	3.54	3.55	3.50	3.35	3.27	3.25	3.25		
8	3.13	3.14	3.10	3.14	3.20	3.26	3.31	3.37		
9	3.09	3.11	3.33							
10		3.80								

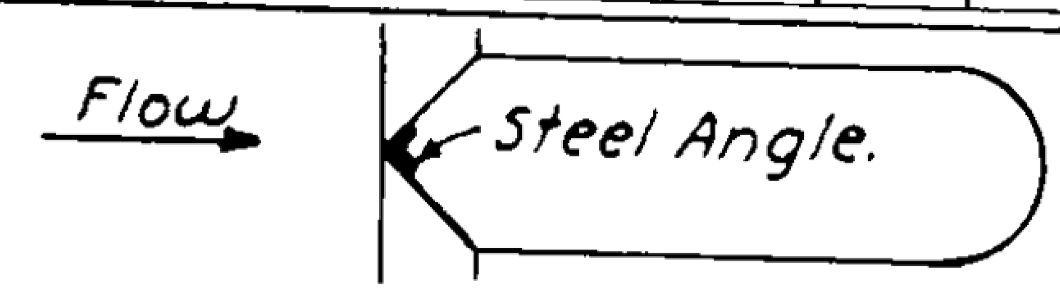


FIG. C - TYPICAL ICE-BREAKER FOR SPILLWAY.

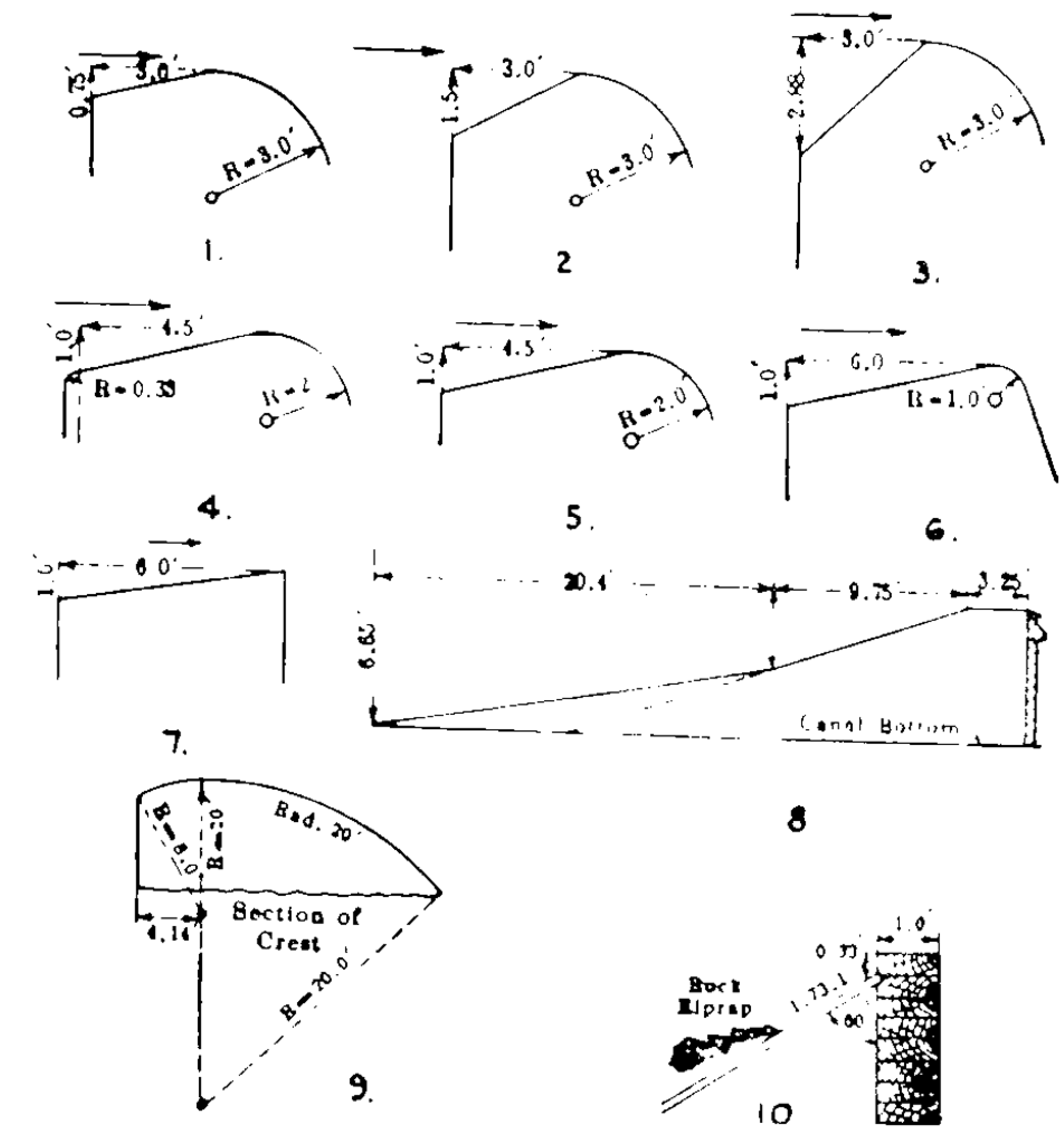


FIG. B - TYPICAL SPILLWAY CRESTS.*

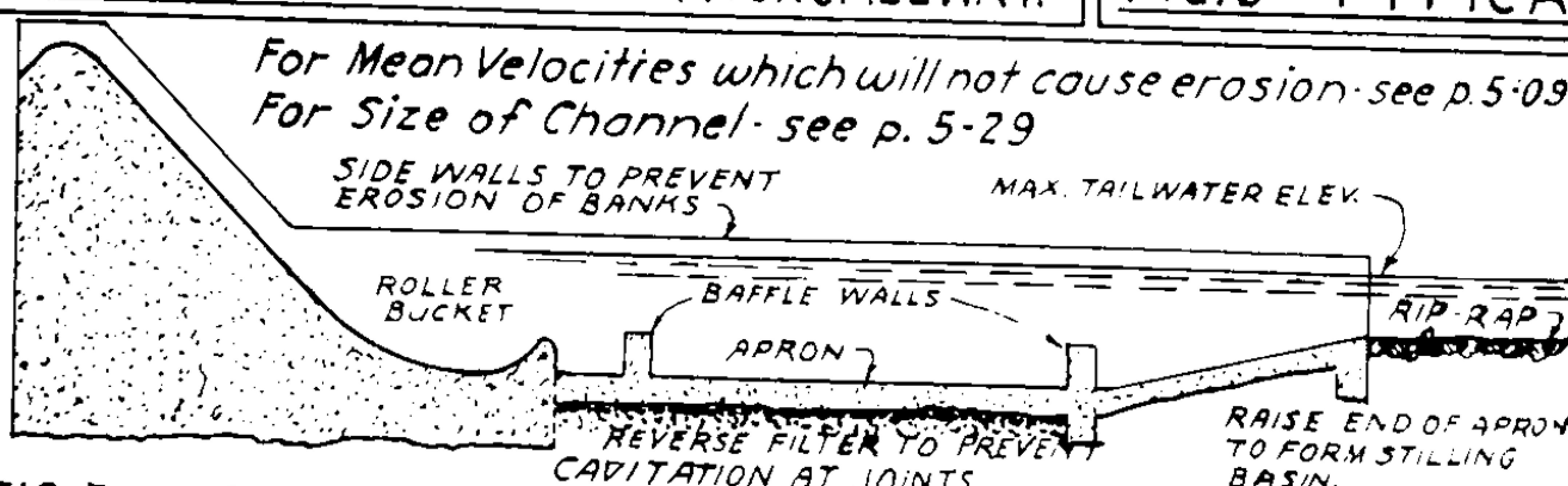
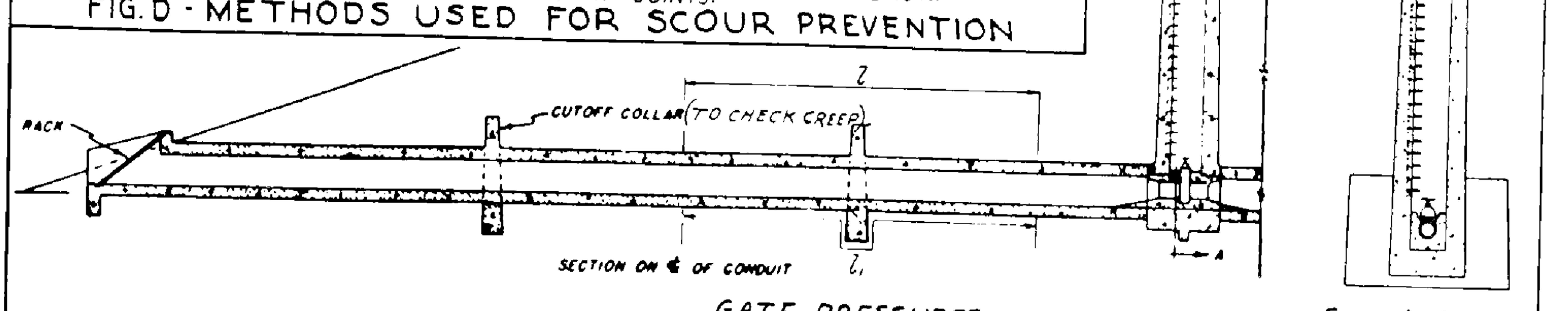


FIG. D - METHODS USED FOR SCOUR PREVENTION



TO CHECK CREEP Along structure: MAKE $l_1 > 1.25l$

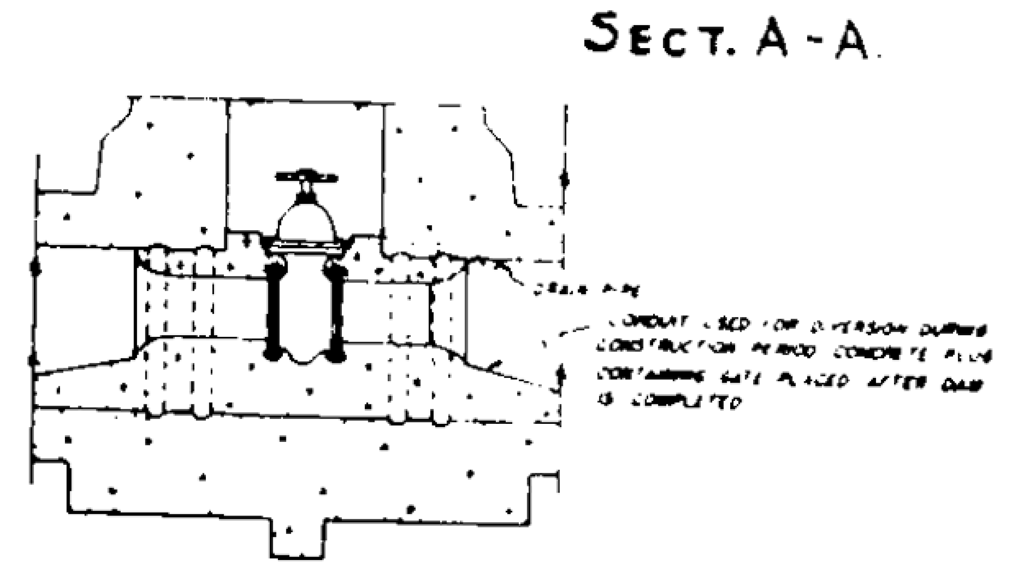
TO DETERMINE PIPE SIZE REQUIRED: SEE Pg. 6-63.

GATE PRESSURES.
To DETERMINE FORCE To OPEN GATES:

To Start $= 0.75\, h \times$ Area

After Start $= 0.40\, h \times$ Area of Gate

h = head to center of gate.



DETAIL OF GATE VALVE INSTALLATION.

FIG. D - TYPICAL PIPE OUTLET THROUGH DAM.**

*Adapted from King, Handbook of Hydraulics, McGraw-Hill.

** From Low Dams by National Resources Comm.

DAMS - WHAT THE FLOW NET SHOWS - 1

"While nature is a fickle jade, she is far kinder to those who study her laws." Lazarus White and Edmund Astley Prentis.

Quick material occurs where particles are floated by upward hydraulic force. This occurs in sand approximately where:

$$\frac{\text{Loss of Head}}{\text{Horizontal Distance}} = 1$$ (See page 4-75 for Flotation Gradient).

Quick material tends to lose its supporting power.

Bull's liver is fine sand which retains water and is quaky - 0.005 to 0.01 mm., requires only a small volume of water to boil. Coarse sands require a large volume of water to boil.

Flow nets are obtained by models and/or by analysis. This preparation requires special skill.

The reverse filter allows added stability under greater head of water.
Used to assist in excavation below ground water level.
Use with caution.

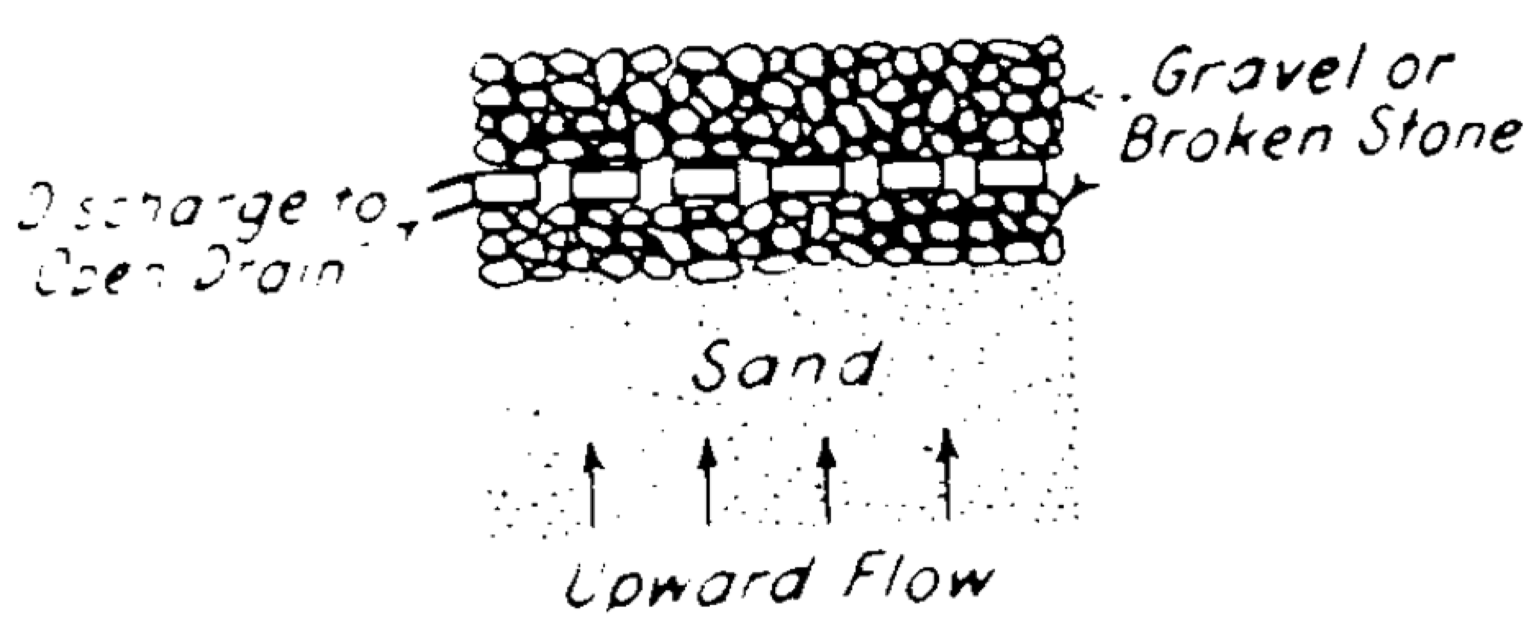


FIG. A- REVERSE FILTER.*

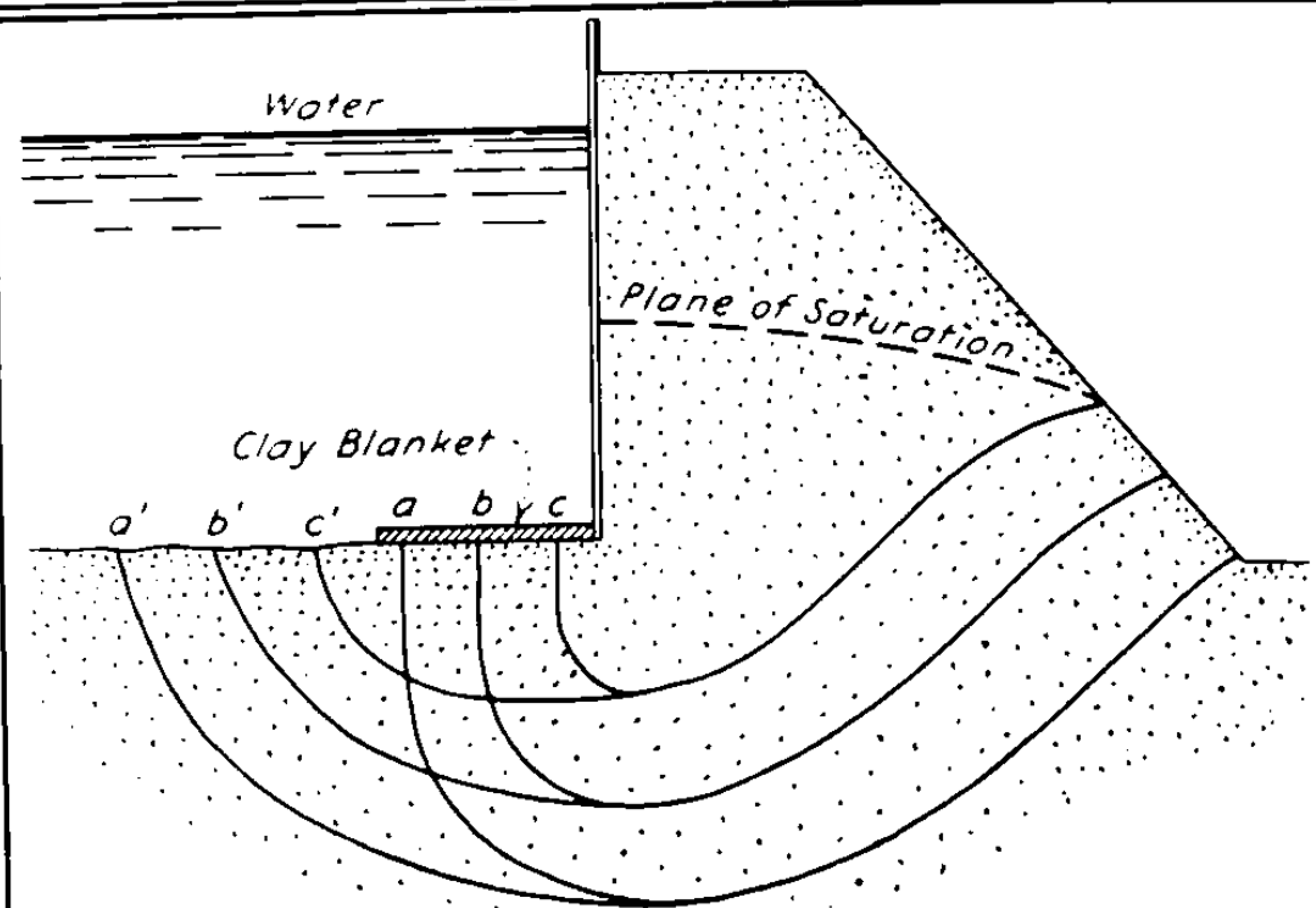


FIG. B- ILLUSTRATING SMALL EFFECT OF CLAY BLANKET IN A COFFERDAM.*

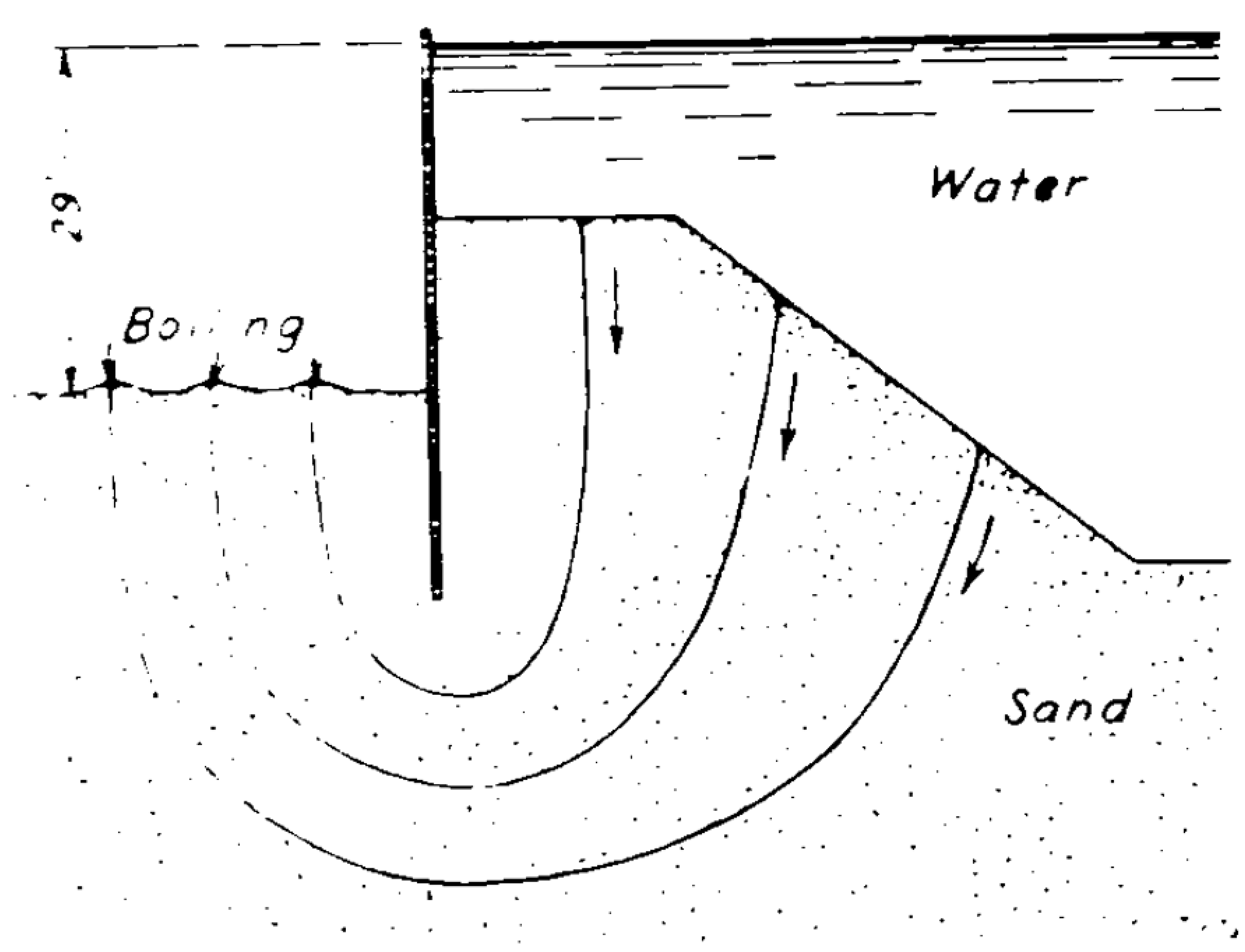


FIG. C- ILLUSTRATING INCORRECT PLACING OF BERM IN A COFFERDAM.*

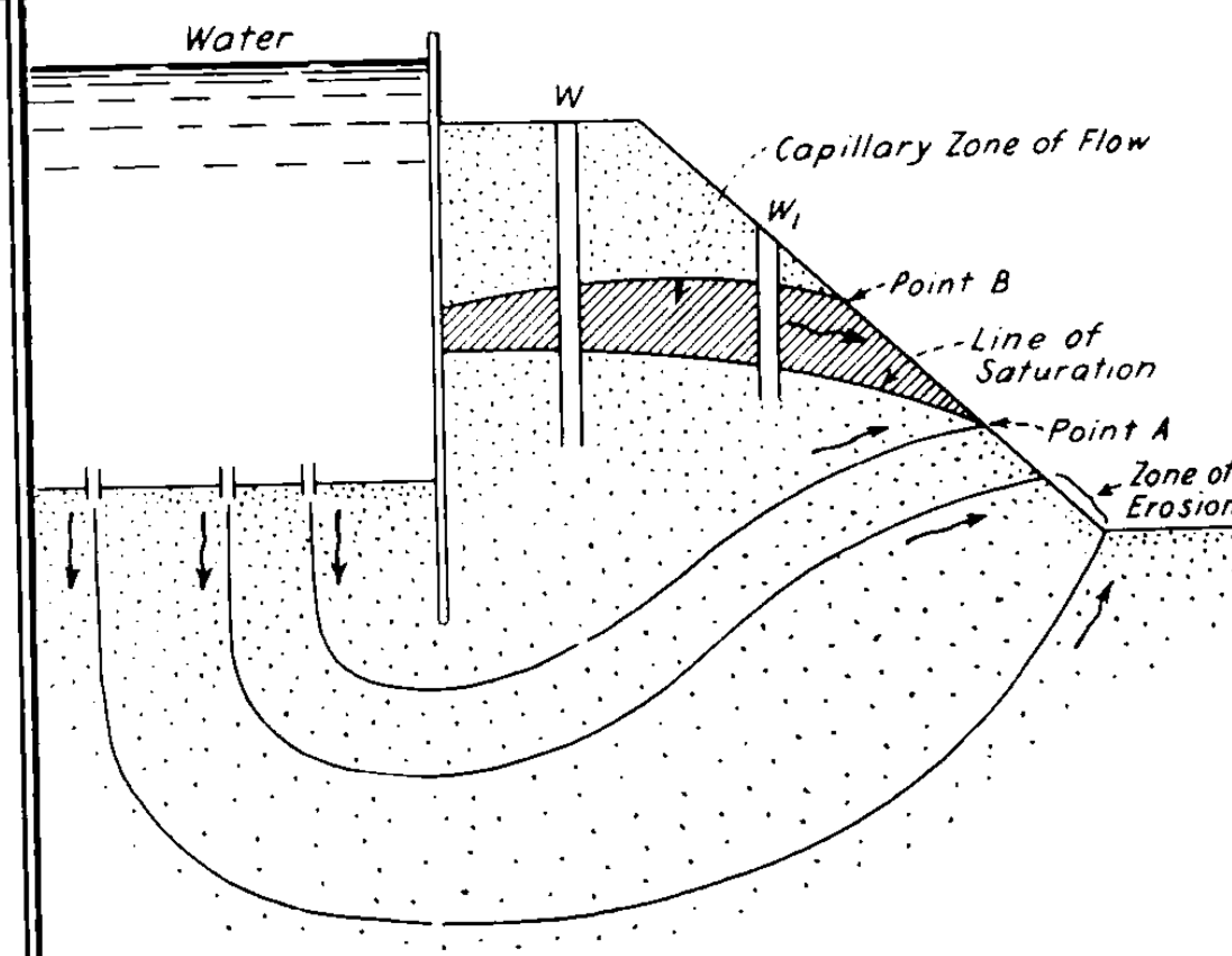


FIG. D- ILLUSTRATING CORRECT PLACING OF BERM IN A COFFERDAM.*

*Adapted from White & Prentis, Cofferdams, By permission of Columbia University Press.

DAMS - WHAT THE FLOW NET SHOWS - 2

NOTE: Full lines represent flow lines after addition of special feature; dotted lines before.

The lines of percolation tend to slough off slope because of saturation.
Remedy: A reverse filter, or rock toe with a drain.

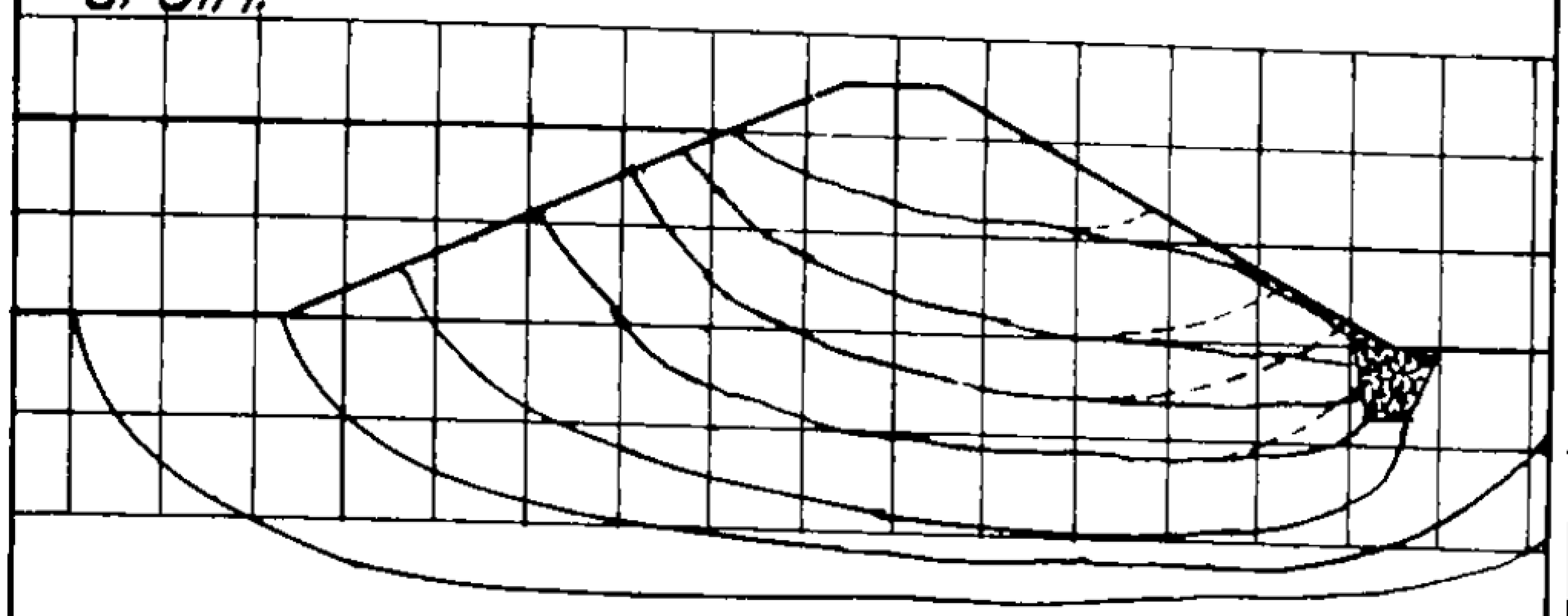


FIG. A- EFFECT OF FILTER AT TOE OF SLOPE.*

Additional fill placed ontop of down-stream slope does not remedy a saturated toe.

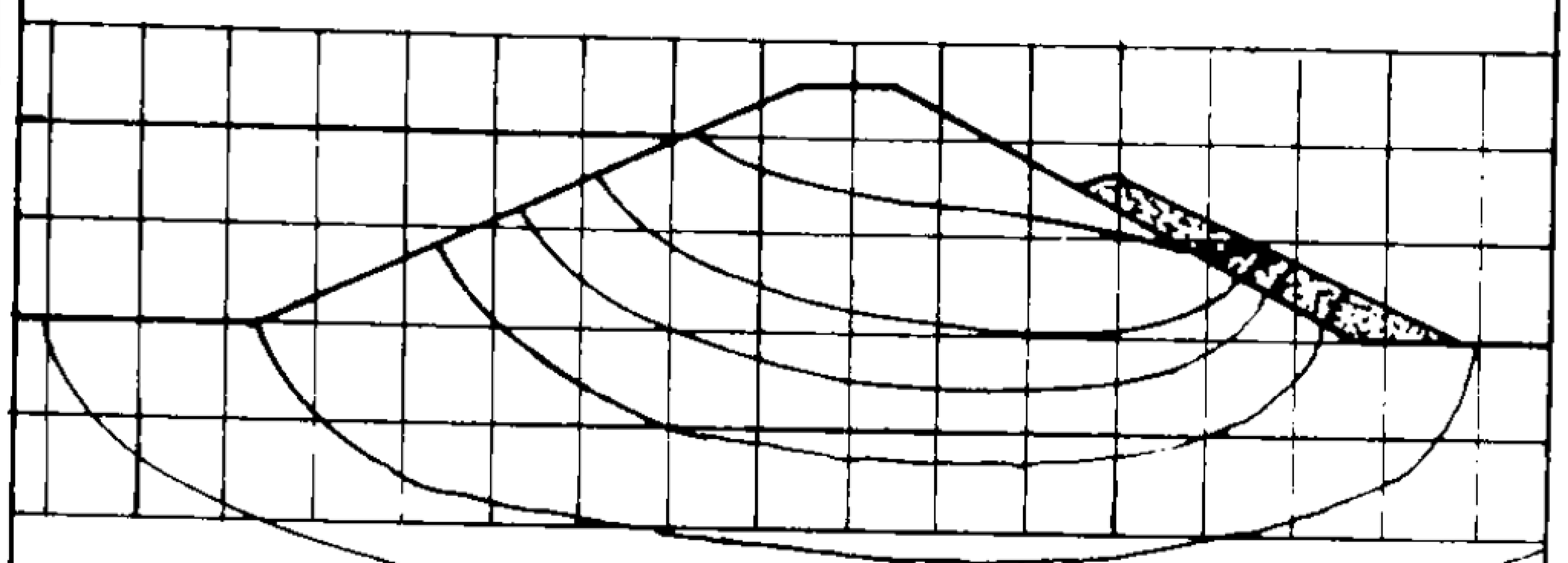


FIG. B - INCORRECT REMEDY EFFECT OF ADDED MATERIAL.*

Note improvement in flow lines at toe.

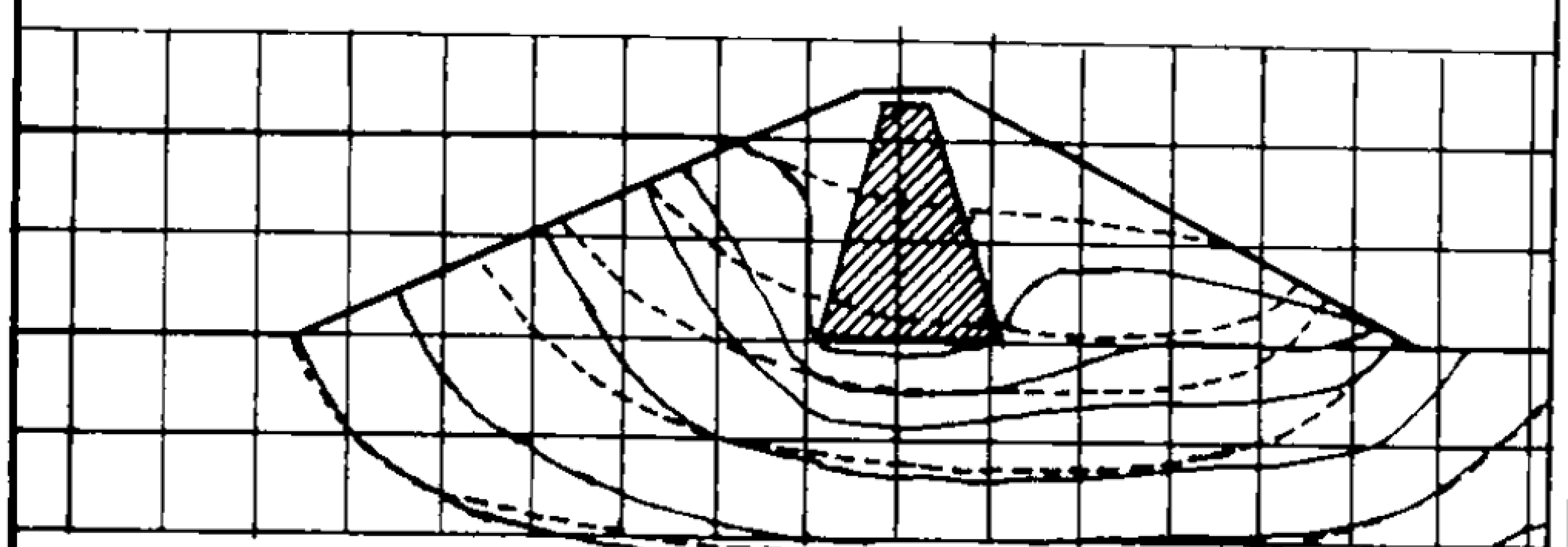


FIG. C- EFFECT OF IMPERVIOUS CORE ON PATH OF PERCOLATION.*

Increased flow concentration at toe is offset by reduced flow pressure.

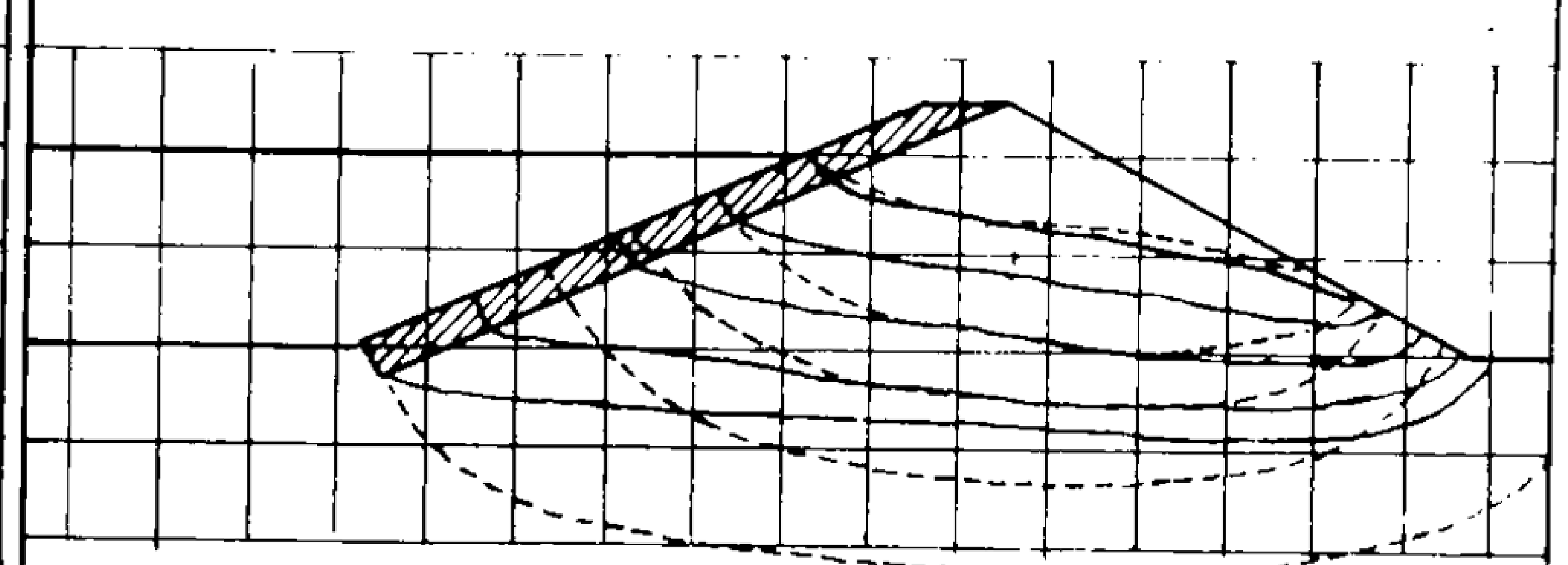


FIG. D- EFFECT OF IMPERVIOUS BLANKET ON UPSTREAM SLOPE.*

Increased flow concentration at toe is offset by reduced flow pressure.

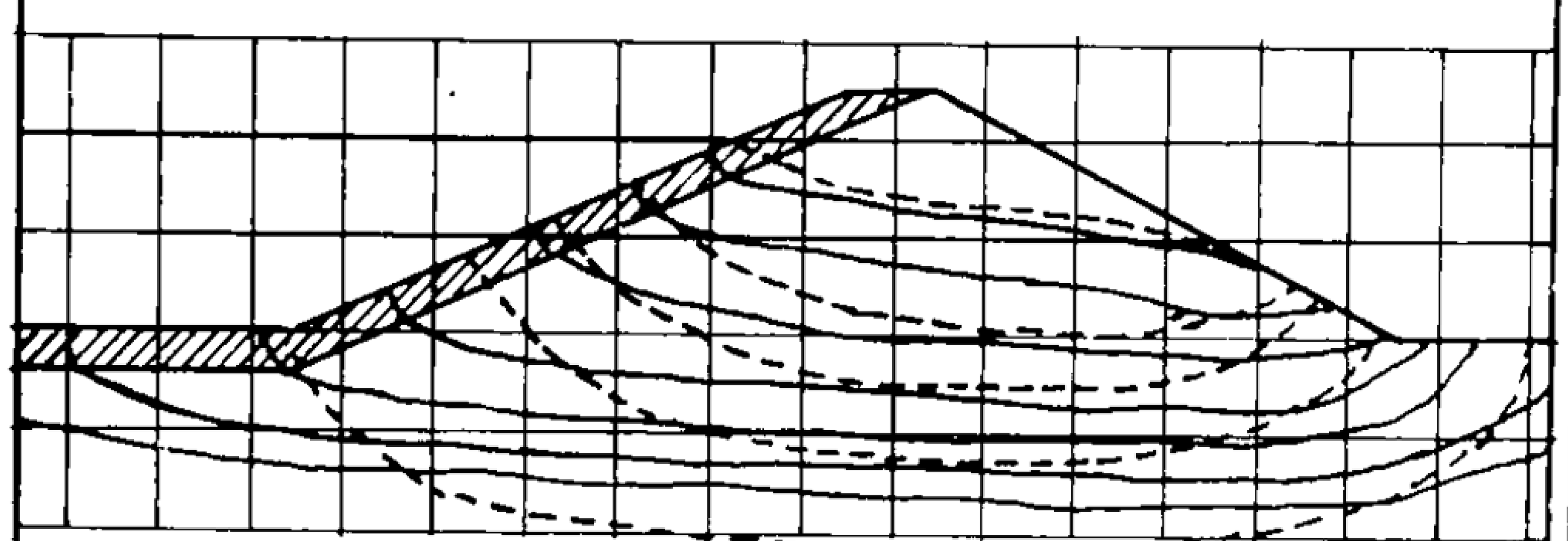


FIG. E- EFFECT OF IMPERVIOUS BLANKET ON UPSTREAM SLOPE & BOTTOM.*

Permeable embankment acts to support the core wall, and as a drain for water percolating through the core.

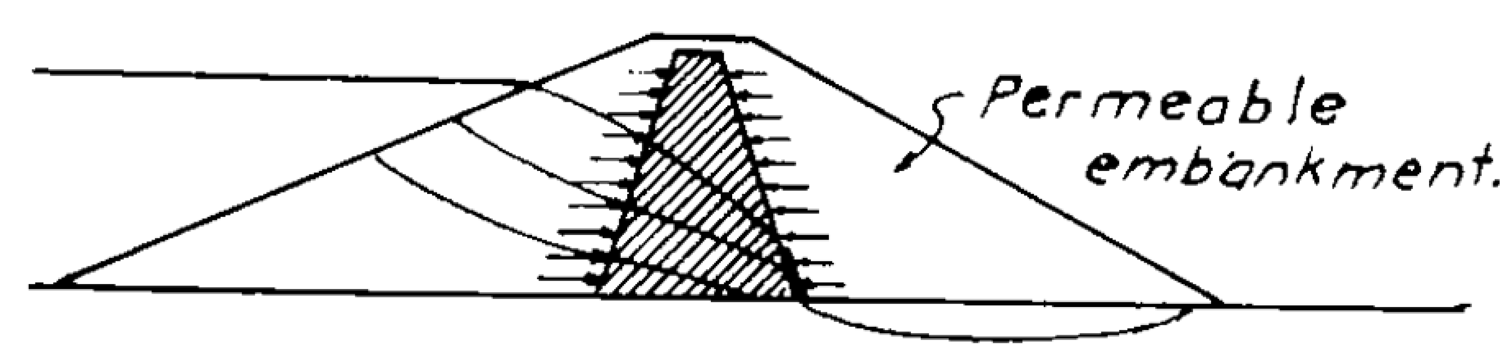


FIG. G- SHOWING HOW CORE WALL IS SUPPORTED BY ADJACENT SLOPES.

Where foundation is pervious, a reverse filter and drain below ground level to carry off waten stabilizes embankment by lowering the water table.

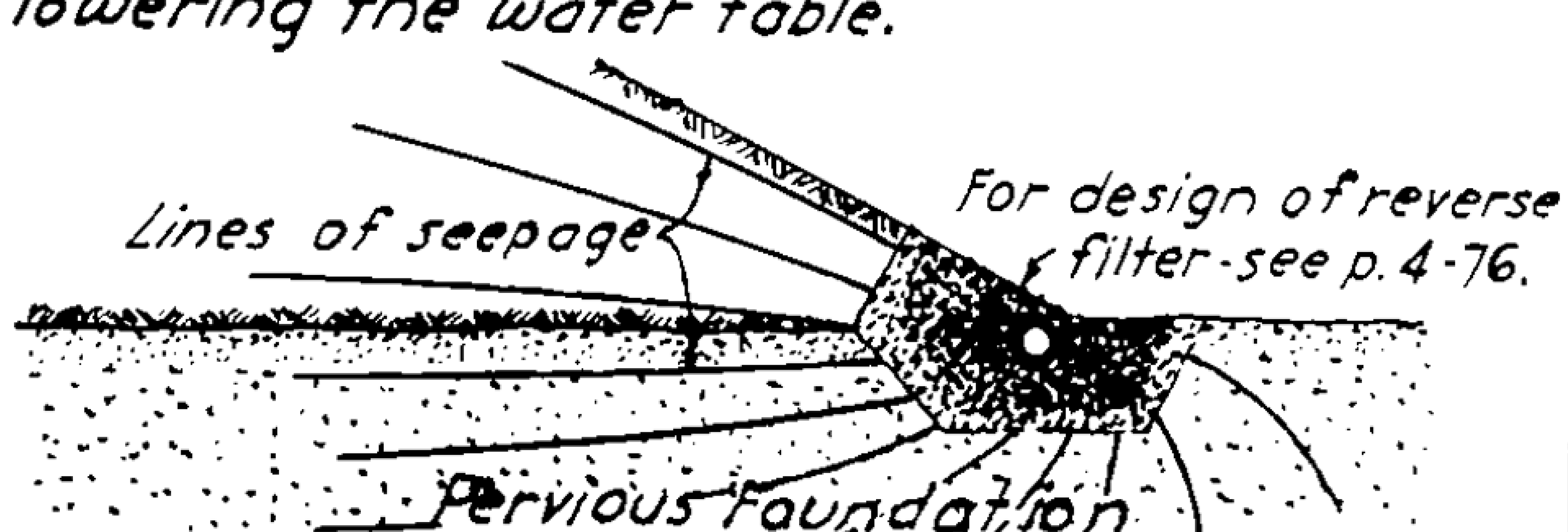


FIG. H - DETAIL OF A REVERSE FILTER AT TOE OF SLOPE.

A slight amount of settlement causes pressure on sheet-piling breaking it or shearing the masonry.

The effect of the cut off is to lengthen the path of seepage.

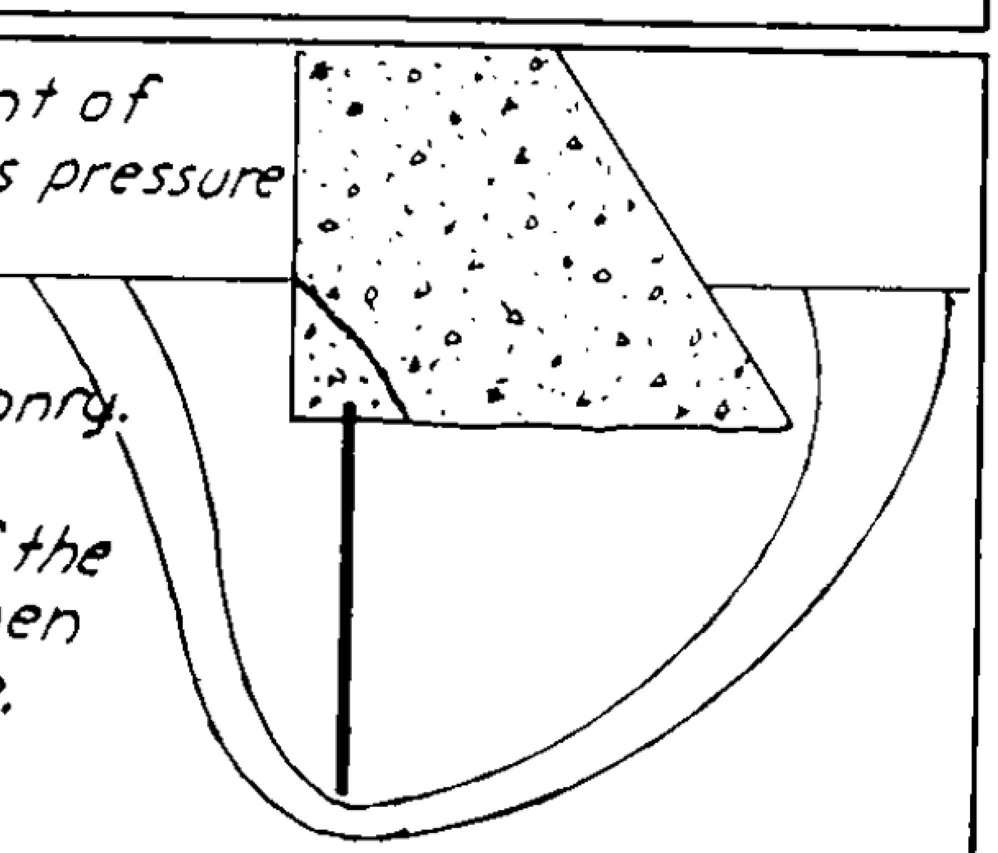


FIG. J - DANGER OF SHEET-PILE CUT OFF UNDER HEEL OF DAM.

**Adapted from Low Dams by National Resources Comm.*

DOCKS & PIERS - GENERAL

TABLE A - WIDTHS OF PIERS.

Freight Piers	10,000 ton ships	single ship.	200 feet.
" "	" " "	one ship each side	300 feet.
" "	" " "	two ships each side	350 feet.
Slips			300 feet.
Quays.			200 feet.

TABLE B - FREEBOARD.

Distance above mean high water 5' to 6' varying with exposure to waves.

TABLE C - DEPTHS OF WATER.

Piers - First Class Pass. - 40' at low water

" " Freight - 35' at low water.

River Steamers - 10-25 feet.

Subject to special study to fit nature of traffic expected.

TABLE D - LIVE LOADS.*

Location	Live Load in Pounds per Square Foot. Lower Deck	Upper Deck
New York Dock Dept. Piers.	500	350
" " " " Bulkhead Walls.	1000	
Havana Steamship Docks.	250	400
Halifax - Concrete Pile Pier No. 2.	1000	500
Philadelphia - Municipal Wharves.	600	300 & 400.
San Francisco - State Piers.	500	
Baltimore - Municipal Wharves.	600	
Tampico - Oil Dock.	800	

SMALL PIERS - WAVE ACTION

$$P = 125 h^2 \times \tan\theta$$

Point of Application $= \frac{3}{8} h$

Where: P = Pressure in lb. per lin. ft.

h = Height of wave in feet.

θ = Maximum angle between ℄ pier and wave front (Min. $\theta = 15°$).

Example:

Given: Pier 90% open; wave = 20'; pier ⊥ wave front.

Required: To find "P."

Solution: Min. $\theta = 15°$ ∴ $\tan\theta = 0.27$

$P = 125 \times 20^2 \times (1.00 - .90) \times 0.27$

$P = 135$ lb. per lin. ft.

PRESSURE OF FLOWING WATER ON OBSTRUCTIONS - CURRENT PRESSURE

$$P = \frac{KWV^2}{64.4}$$

Where: V = Velocity of Current - ft./sec.

P = Pressure in lb. per square foot

W = Weight of water in lb. per cu. ft.

K = a constant.

$\frac{KW}{64.4} = 1.5$ for flat surfaces.

$= 0.75$ for round surfaces.

NOTE:

Use 150 lb. per square foot minimum for streams subject to freshets.

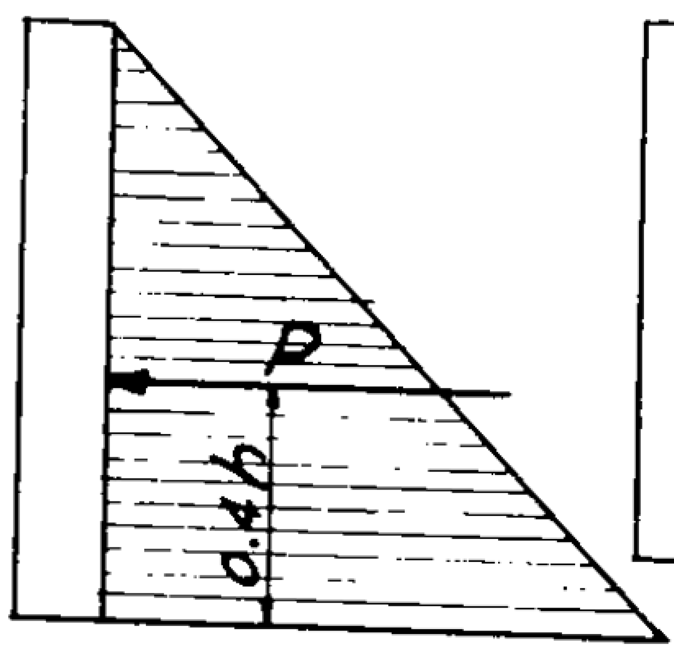
SHOCK PRESSURE: Pierhead bent to be designed for a horizontal thrust equal to 1% of max. weight of vessel to be berthed.**

*Adapted from Greene, Wharves & Piers, McGraw-Hill.

**Calculations by the author assume a permissible horizontal deflection of pierhead of 6" and a glancing blow equal to 1/10 of kinetic energy produced by a velocity of 1 mile per hour.

DOCKS & PIERS - THRUSTS AGAINST DOCKS

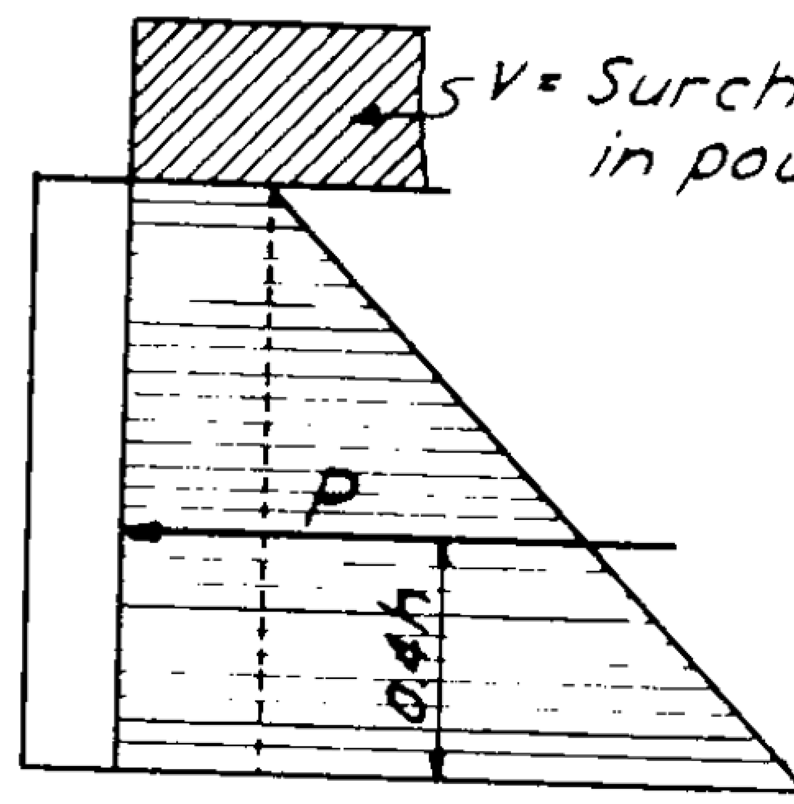
$$P = \tfrac{1}{2} w h^2 \tan^2(45° - \tfrac{\phi}{2}).$$



NOTATION.
P = Force in pounds per l.f.
w = Weight of soil in pounds per cubic ft.
h = Height of wall in ft.
ϕ = Angle of slope
See pg. 3-23.

CASE I - EARTH.

$$P = (\tfrac{1}{2} w h^2 + v h)(\tan^2 45° - \tfrac{\phi}{2}).$$

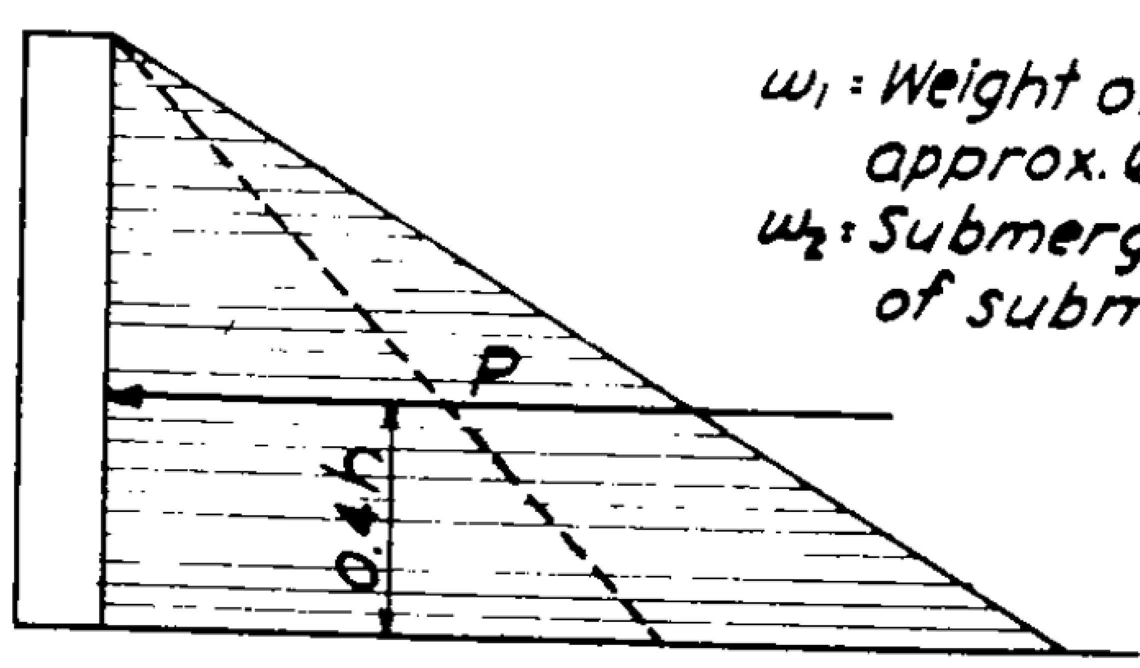


V = Surcharge load in pounds per sq. ft.

CASE II - EARTH & SURCHARGE.

$$P = \tfrac{1}{2} h^2 (w_1 + w_2 \tan^2 45° - \tfrac{\phi}{2})$$
$$= \tfrac{1}{2} h^2 W$$

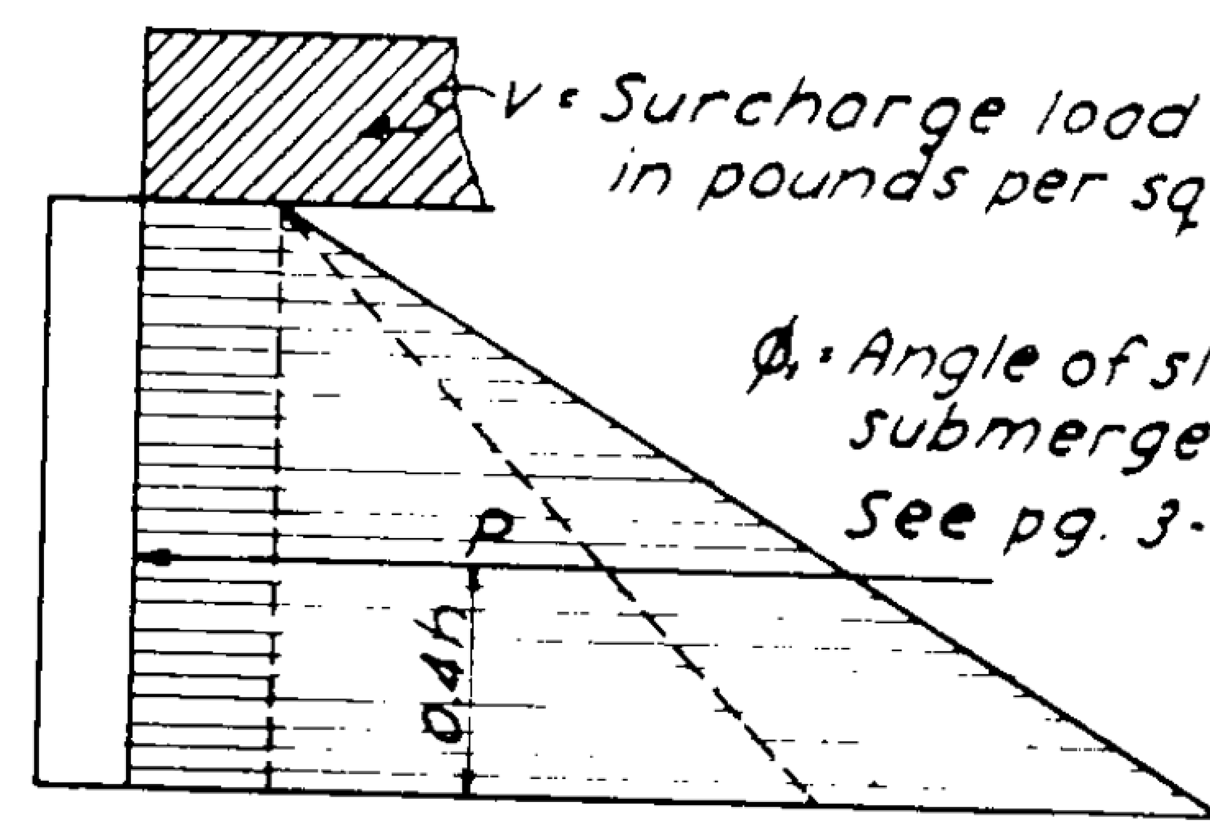
For values of W see Table B.



w_1 = Weight of sea water. approx. 64 lb. per cu. ft.
w_2 = Submerged weight of submerged earth.

CASE III - SUBMERGED EARTH.

$$P = v h (\tan^2 45° - \tfrac{\phi_1}{2}) + \tfrac{1}{2} h^2 W.$$



V = Surcharge load in pounds per sq. ft.

ϕ_1 = Angle of slope of submerged earth.
See pg. 3-23.

CASE IV - SUBMERGED EARTH & SURCHARGE.

TABLE A - WEIGHT OF SOILS SUBMERGED.*

MATERIAL.	POUNDS PER CUBIC FOOT.		
	MAXIMUM	MINIMUM	AVERAGE
Gravel and Marl.		42.0	62.9
Gravel and Sand.	73	42.0	62.4
Sand.	66	42.0	58.3
Gravel, Sand & Clay.	80.9	51.2	70.0
Stiff Clay.	64.8	38.4	47.8
Stiff Clay & Gravel.	70.3	44.8	52.6

Weights are for soils submerged in sea water.

TABLE B - VALUES OF W*

Combined Weight W of Sea Water and Earth, Lb. per Cu. Ft.
(Equivalent Fluid Pressure)

Slope of repose of earth	Weight w_2 of submerged earth, lb per cu. ft. - See Table A.							
	40	44	48	52	56	60	64	68
1/2 : 1	66.2	66.4	66.7	66.9	67.1	67.3	67.6	67.8
3/4 : 1	68.4	68.9	69.3	69.8	70.2	70.7	71.1	71.6
1 : 1	70.9	71.6	72.2	72.9	73.6	74.3	75.0	[illegible]
1-1/4 : 1	73.2	74.2	75.1	76.0	76.9	77.9	78.8	79.7
1-1/2 : 1	75.4	76.6	77.7	78.9	80.0	81.2	82.3	83.5
1-3/4 : 1	77.5	78.8	80.2	81.5	82.9	84.2	85.6	86.9
2 : 1	79.3	80.8	82.3	83.9	85.4	86.9	88.4	90.0
2-1/2 : 1	82.3	84.2	86.0	87.8	89.7	91.5	93.3	95.2
3 : 1	84.8	86.9	88.9	91.0	93.1	95.2	97.2	99.3
3-1/2 : 1	86.8	89.0	91.3	93.6	95.9	98.2	100	102
4 : 1	88.4	90.8	93.3	95.7	98.1	101	103	105
5 : 1	90.9	93.6	96.3	99.0	102	104	107	109
6 : 1	104	108	112	116	120	124	128	132

TABLE C - VALUES OF $\tan^2(45° - \frac{\phi}{2})$.

SLOPE	ANGLE ϕ	$\tan^2(45° - \phi/2)$	SLOPE	ANGLE ϕ	$\tan^2(45° - \phi/2)$
1 on 4	14°-10'	0.607	1 on 2	26°-50'	0.383
1 on 3½	16°-0'	0.567	1 on 1½	33°-40'	0.287
1 on 3	18° 30'	0.518	1 on 1⅓	36°-50'	0.250
1 on 2½	21° 50'	0.458	1 on 1	45° 0'	0.172

*Adapted from American Civil Engineers' Handbook by Merriman & Wiggin.

DOCKS & PIERS - QUAYS - BULKHEADS

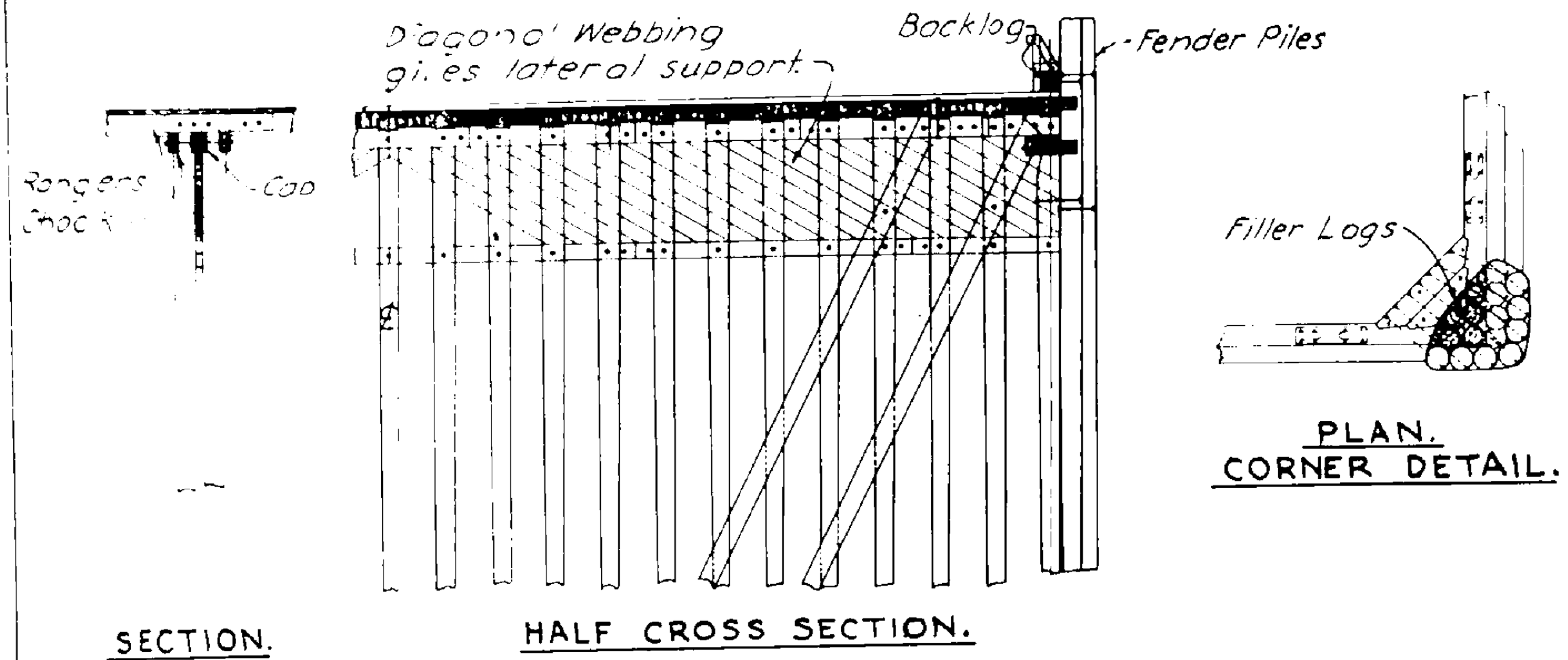


FIG. A - ARMY PIER AT PIERMONT, N.Y.

Heavy duty type similar to New York Dock Dept. practice. These piers have an approximate horizontal thrust resistance of 5 tons per linear foot.
Note: Exposed to heavy ice flow of Tappan Zee (Hudson River).

NOTE: Backfill in these cases should be made from outside toward shore to reduce mud-wave action.

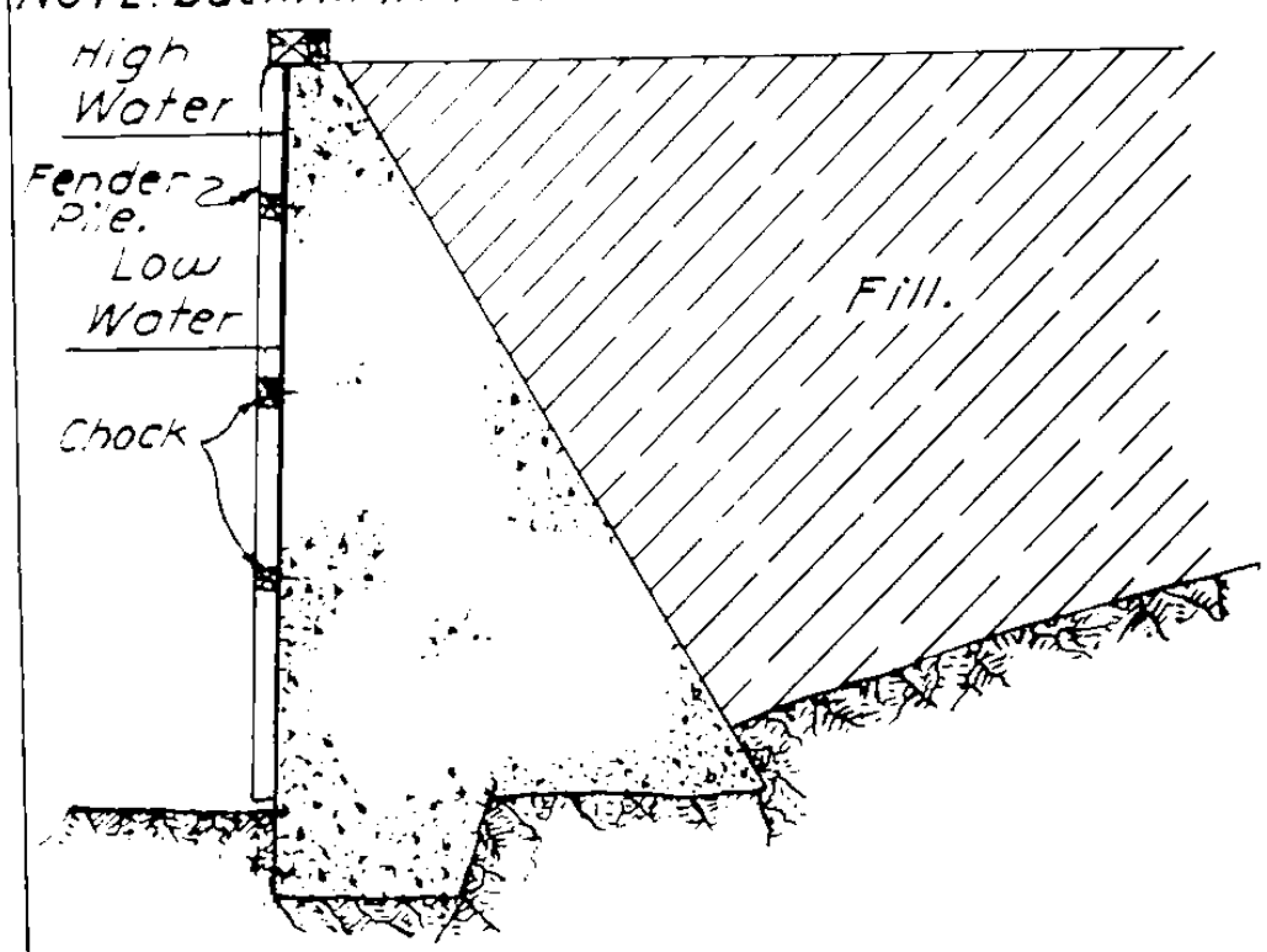


FIG. B - RETAINING WALL

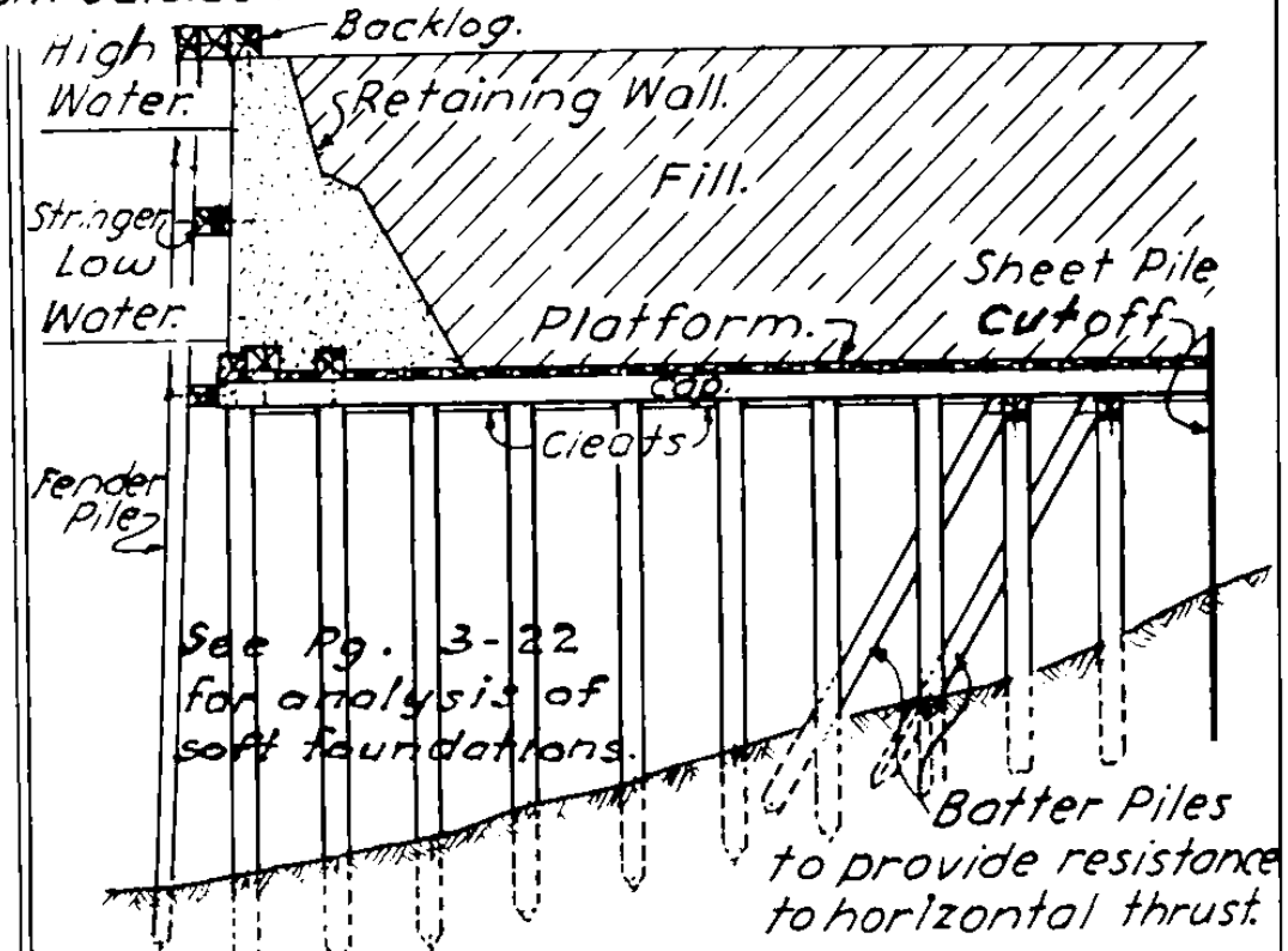


FIG. C - RELIEVING PLATFORM.

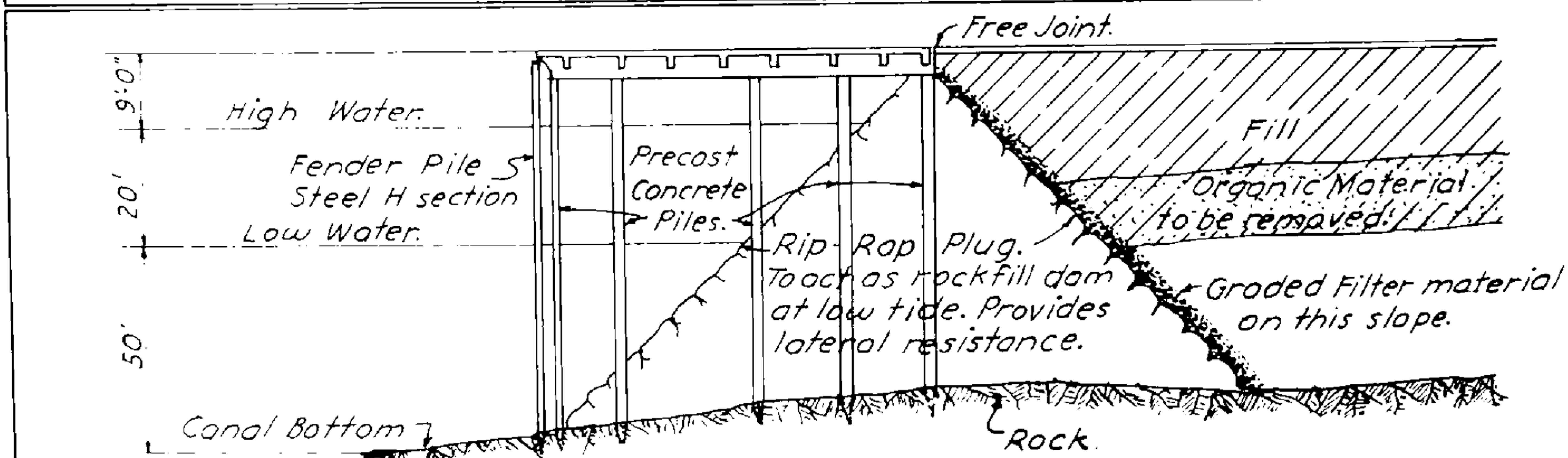


FIG. D - SLIPSIDE DOCK - TYPE FOR HIGH TIDES (PROPOSED DOCK AT PANAMA).

DOCKS & PIERS - AUXILIARY STRUCTURES

DOLPHINS:

Are islands of piles tied together with bolts and wire cables to protect docks from ice and wearing of ships.

GROINS:

Are bulkheads built at angles to a beach and across it to prevent lateral scour, build up beach and to protect the foundation of sea walls from scour.

Spacing is a matter of study. A spacing equal to length has been recommended.

Depth is a matter of judgment. 10' below the beach has been recommended.

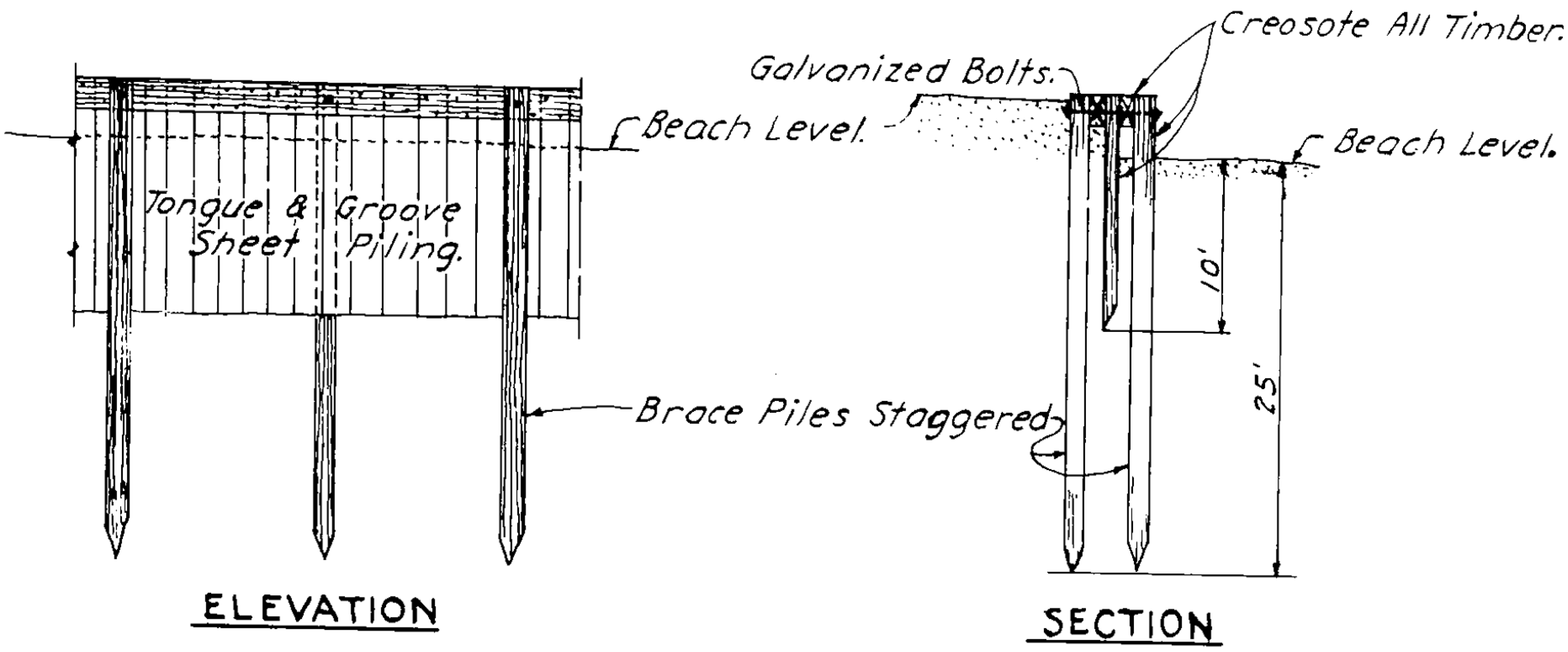
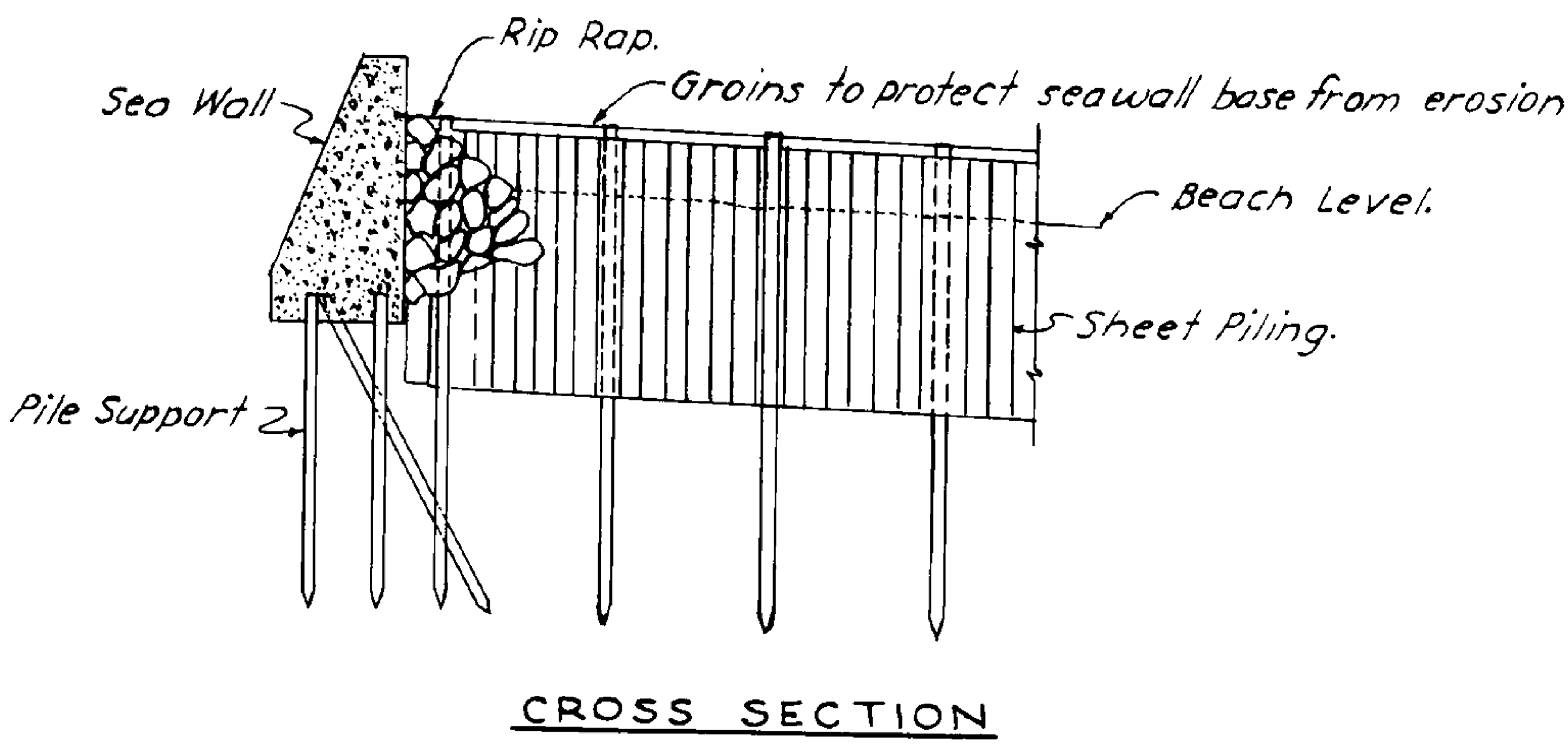


FIG. A - SUGGESTED SECTION FOR GROINS.



Rock Fill for jetties or rip rap on structures subject to ocean wave action should be 1 to 6 tons in size.

FIG. B - ELEMENTS OF SEAWALLS BELOW HIGH WATER.

DOCKS & PIERS — DETAILS

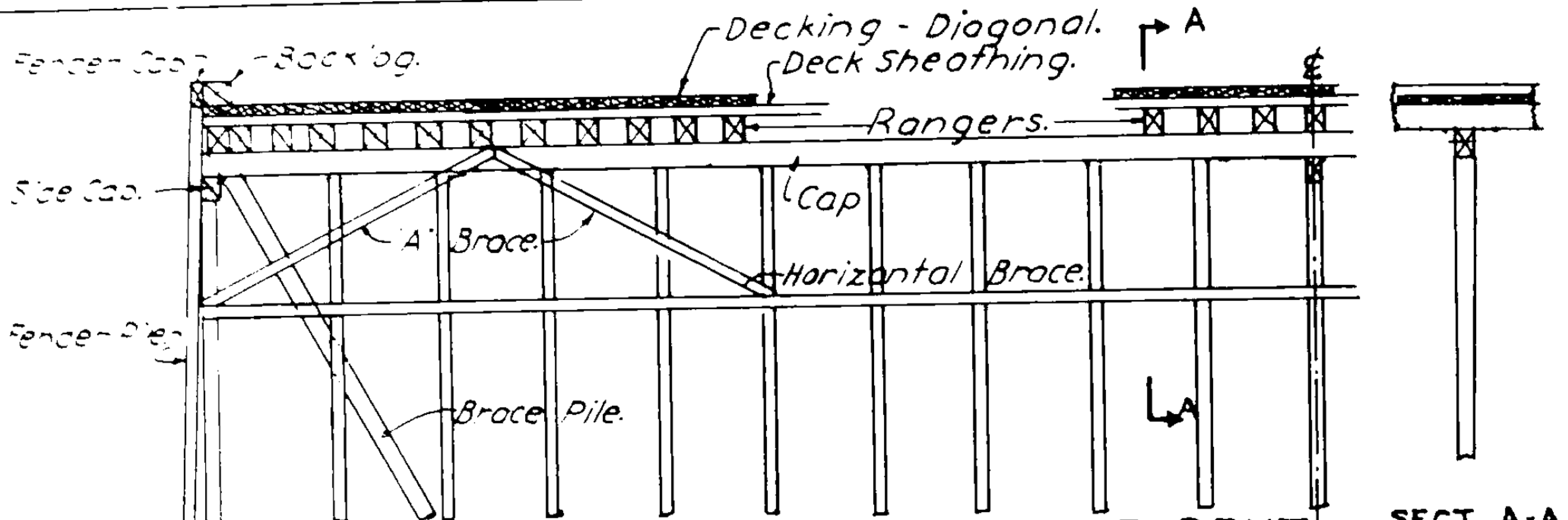


FIG. A - CROSS SECTION - TYPICAL PILE BENT.

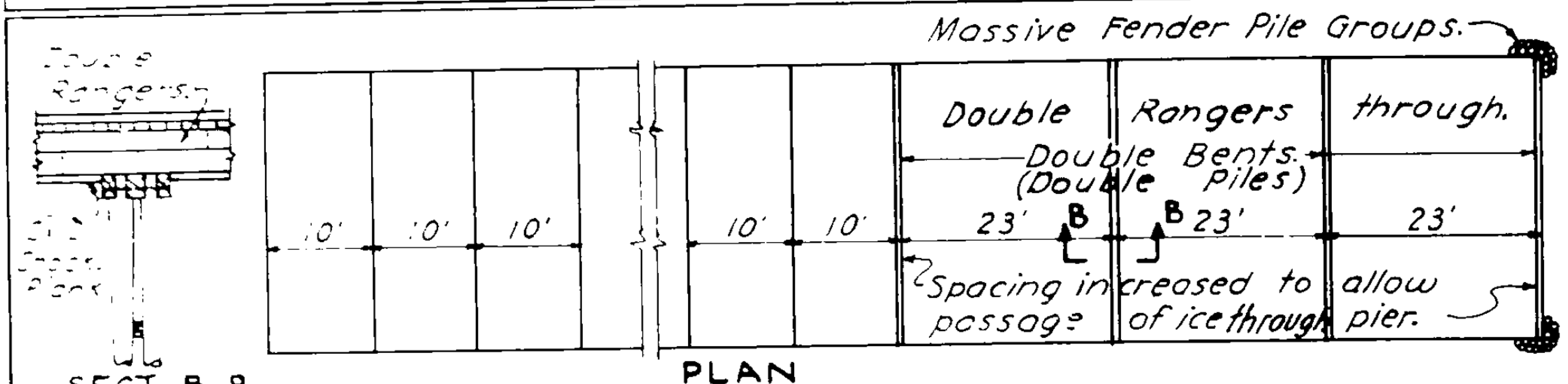


FIG. B - TYPICAL BENT SPACING.

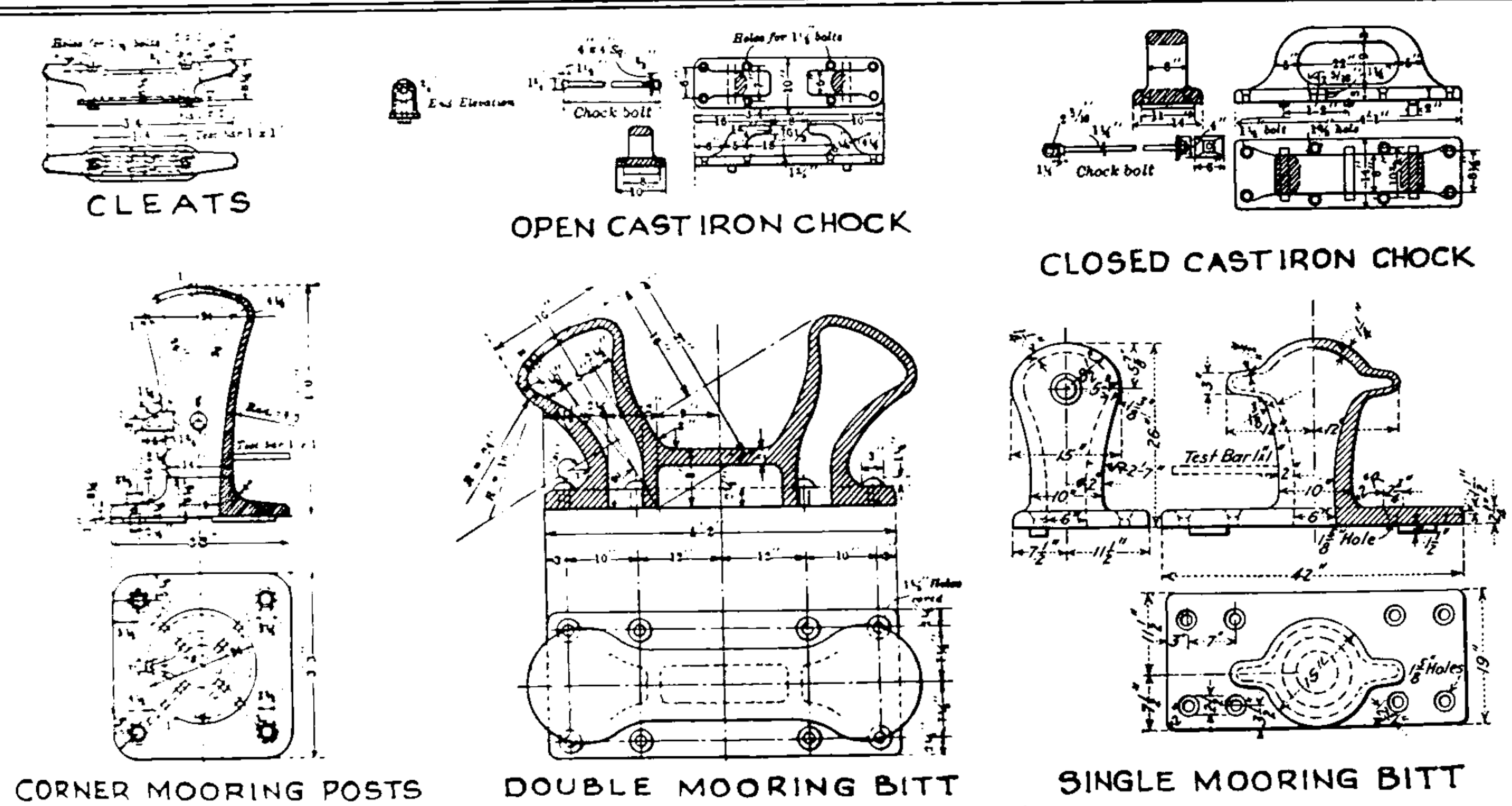


FIG. C - DOCK FITTINGS.*

NOTE: Anchorage strength of fittings should be designed to hold the strength of mooring lines. See Table D.

TABLE D - STRENGTH OF MANILA ROPE.

SIZE OF LINE.	STRENGTH - lbs.
1" Dia.	7,000
2" "	25,000
3¼" "	72,000

*Adapted from American Civil Engineers' Handbook by Merriman & Wiggin.

DOCKS & PIERS - PROTECTION & PILES

MARINE BORERS (TEREDO, etc.):

Creosoting - difficult to provide complete impregnation; partial impregnation leaves heart exposed to attack.

Life of creosoted piles on Pacific Coast - increased by one year for each pound of creosote per cubic foot of material.*

Heavy sewage pollution protects piles.

Earth Protection: When practical earth fill may be placed around piles to protect them against marine borers.

Concrete and Steel Piles are not affected.

CORROSION: *

Life of a steel pile may be estimated by the formula: $Y = W/CL$
where: Y = Life of metal in years; W = Weight of steel per linear foot, L = Perimeter of exposed steel in feet; C = Value given in Table A.

TABLE A - VALUES OF "C".

Foul Sea Air.	0.1944	Pure Air, or Clear River Water	0.0125
Clean Sea Air.	0.0970	Air of Manufacturing Districts & Sea Air.	0.1252
Foul River Water.	0.1133		

Note: Cast Iron has considerably more resistance than structural steel.

Concrete and Steel: Waters subject to industrial waste should be examined for corrosive action and adequate protection given.

EROSION:

Concrete structures subject to abrasion by ice, or freezing and thawing should have protection - such as sheathing or rip-rap.

Wood structures - protect from ships etc. by dolphins, fender piles or sheathing.

DECAY:

Wood - subject to decay above low water level - creosote all exposed material.

SCOUR:

Obstructions such as practically solid piers tend to cause river bottom scour - and should be made subject of special study.

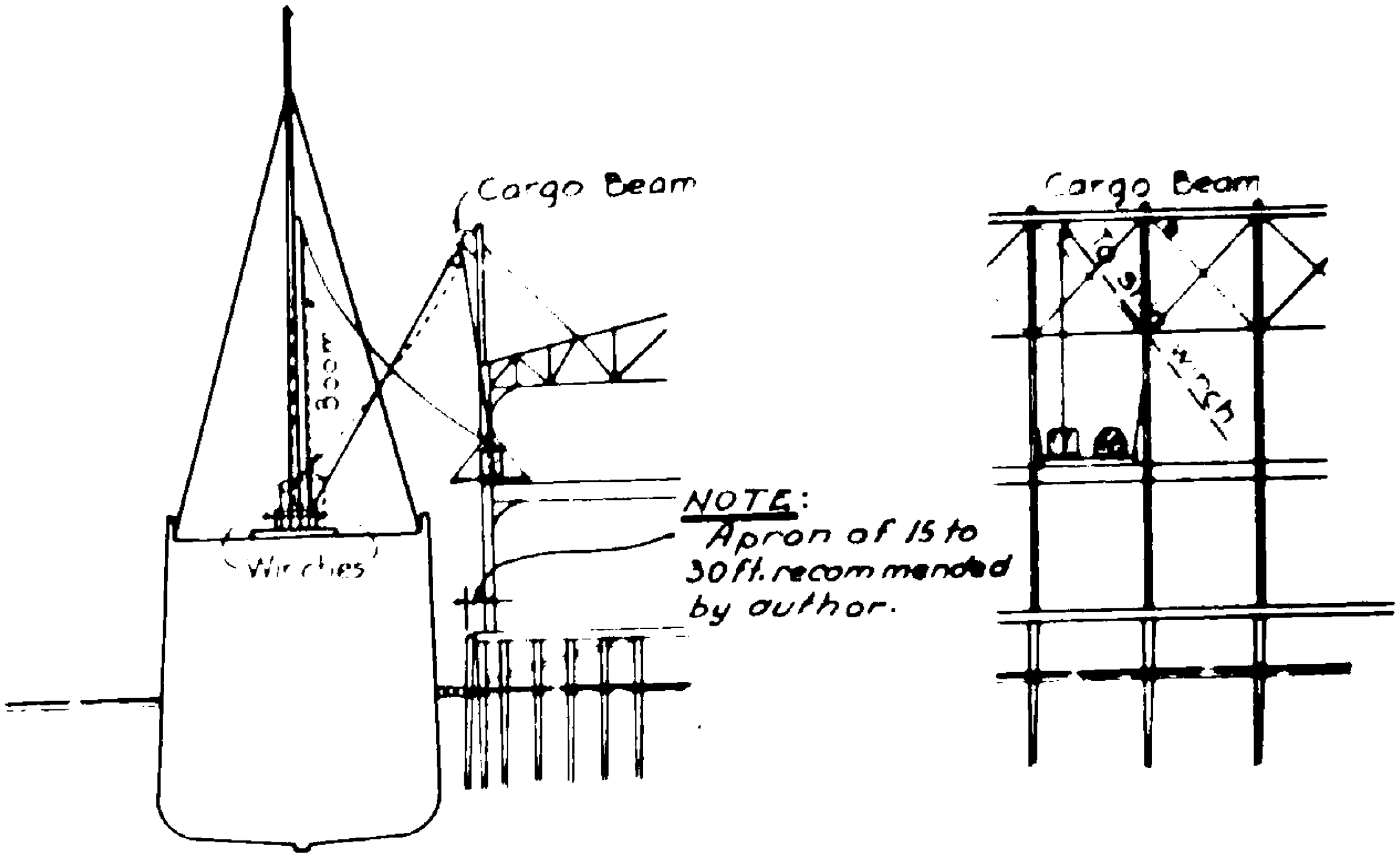
Rip-Rip may be used to minimize scour.

PILE FOUNDATIONS: **

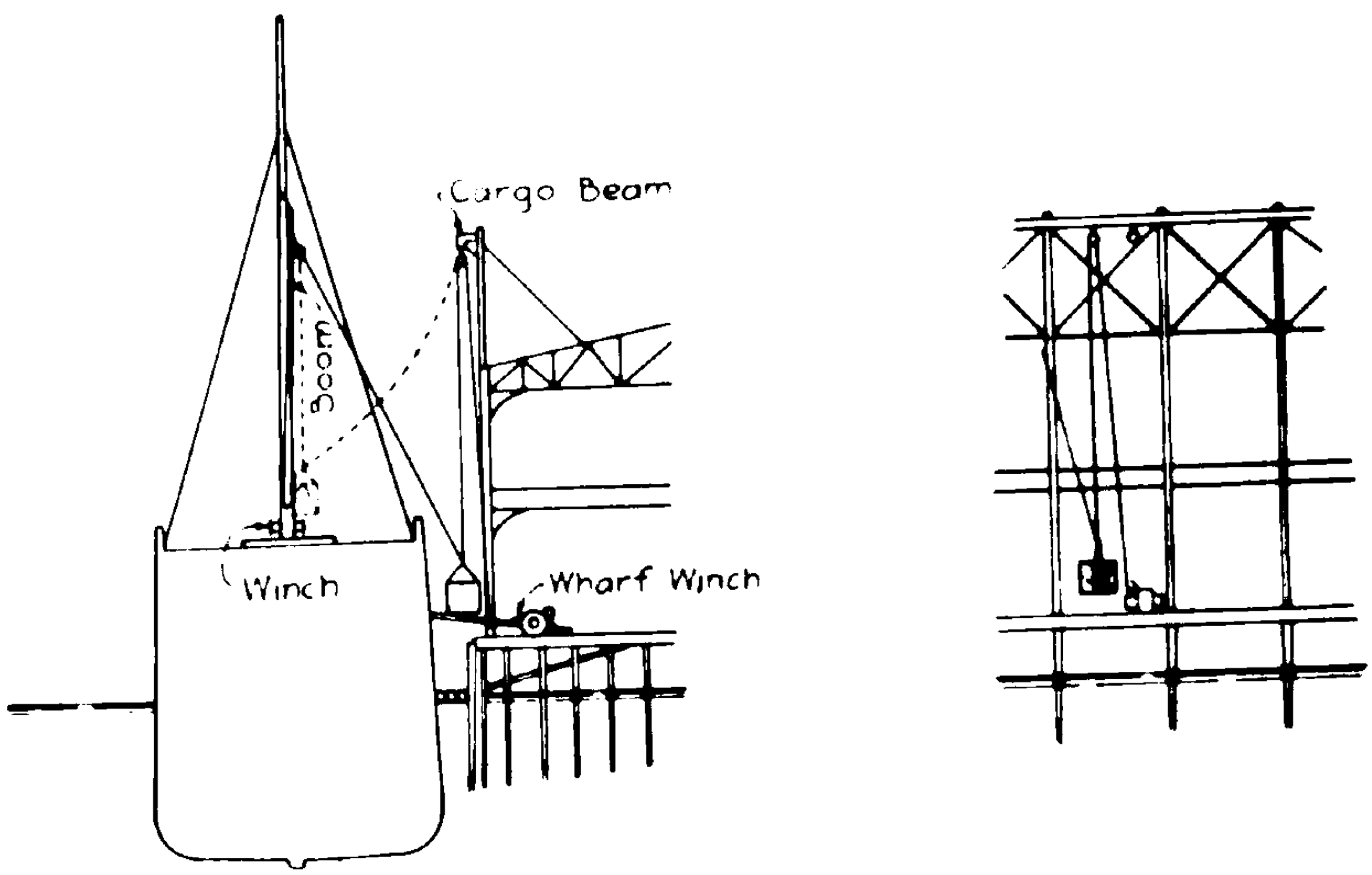
"Conditions of foundations or bottom of harbor should be thoroughly known or studied in order to determine length of piles needed, permissible load for each pile or group of piles, and the character of material to be dredged to obtain required depth of water." See Pg. 2-59 to 2-67 for pile data.

* Adapted from Wharves & Piers by Carleton Greene, McGraw-Hill
** By Col. Marcel Garsaud.

DOCKS & PIERS – CARGO HANDLING – 1



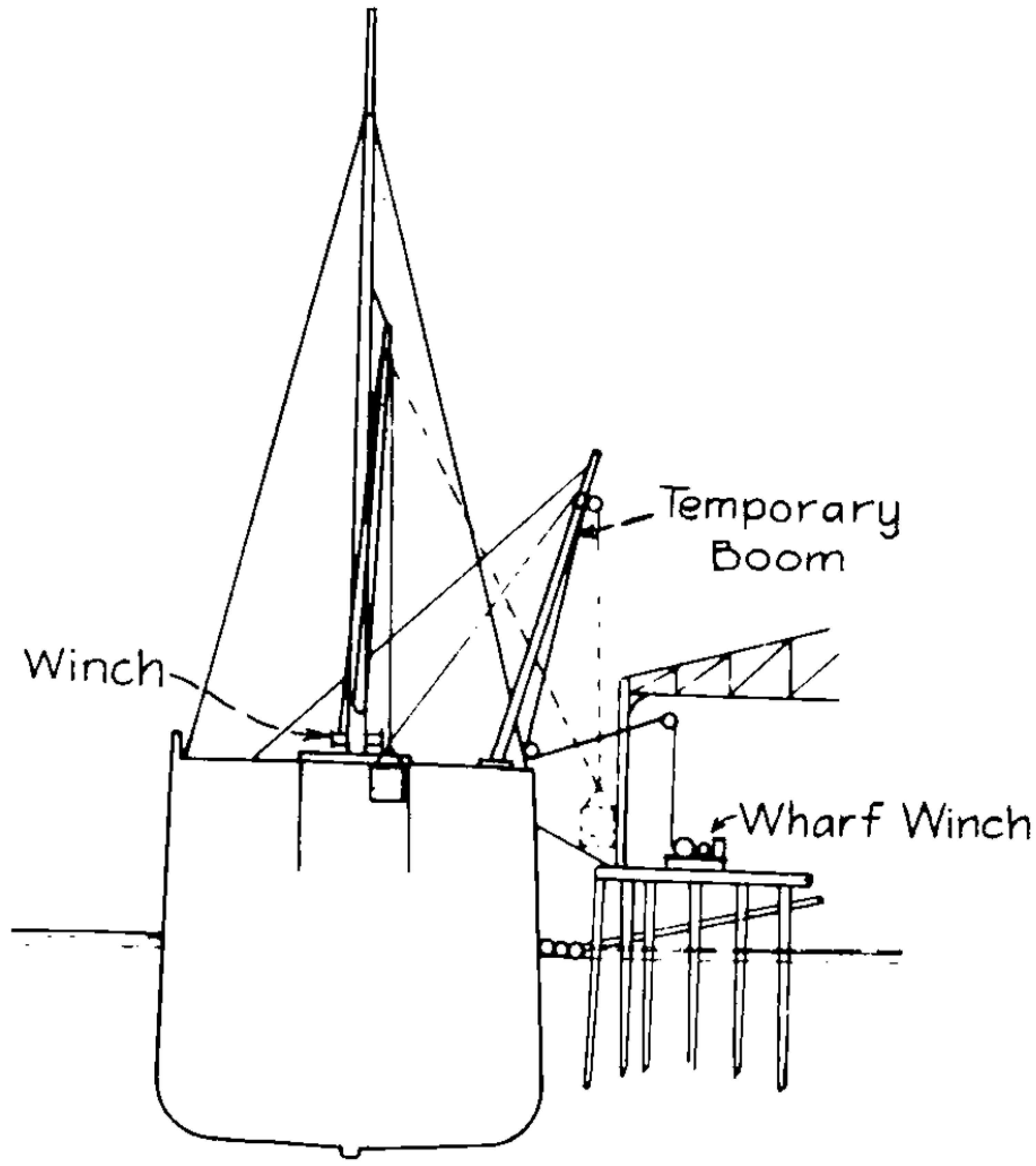
LOADING CARGO USING SHIP'S WINCHES SHIP'S BOOM AND CARGO BEAM ON WHARF



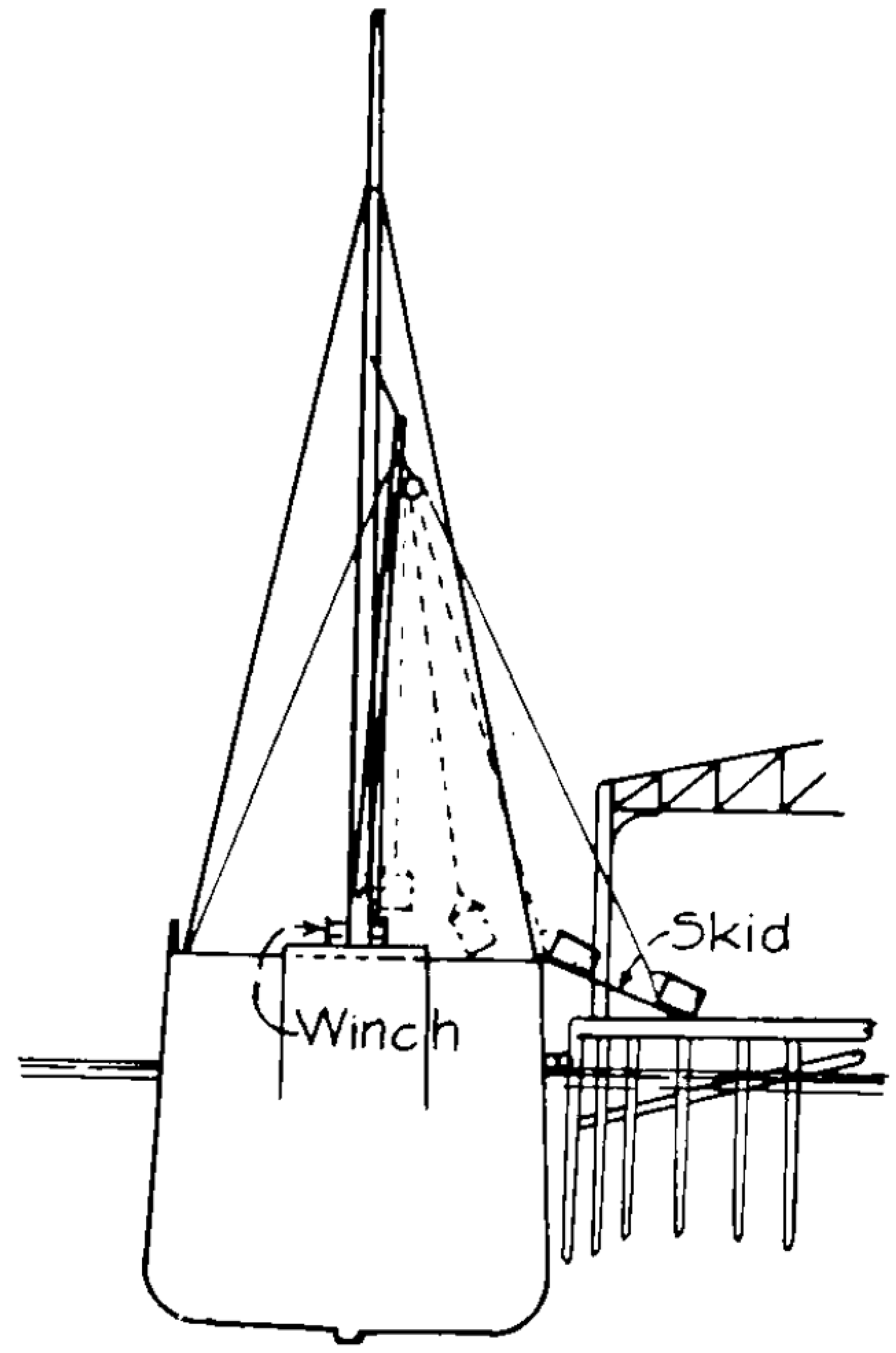
LOADING CARGO USING SHIP'S WINCHES, SHIP'S BOOM, CARGO BEAM AND WHARF WINCH

Adapted from Design of Harbor Structures by Spofford & Thorndike.

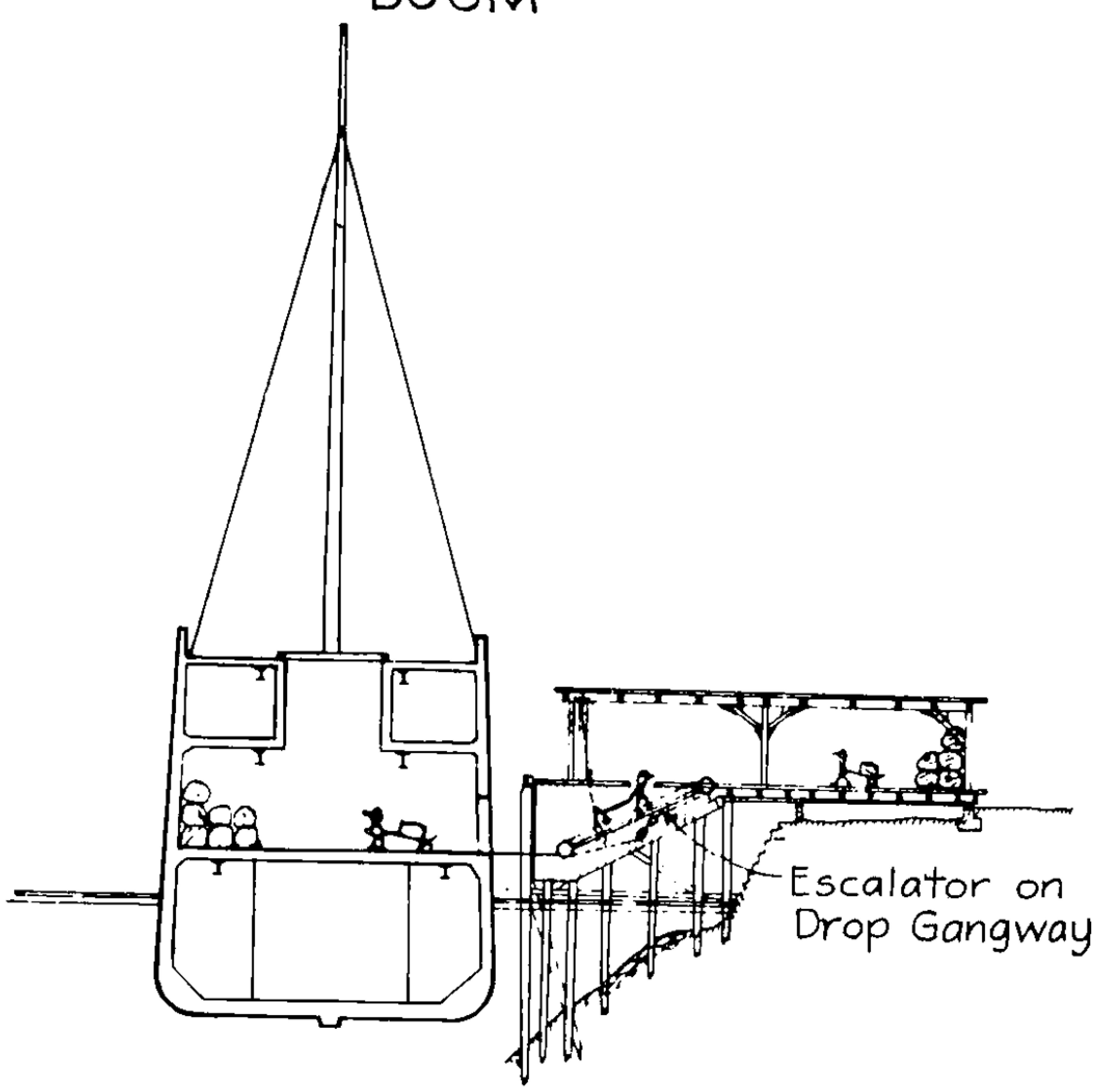
DOCKS & PIERS - CARGO HANDLING - 2



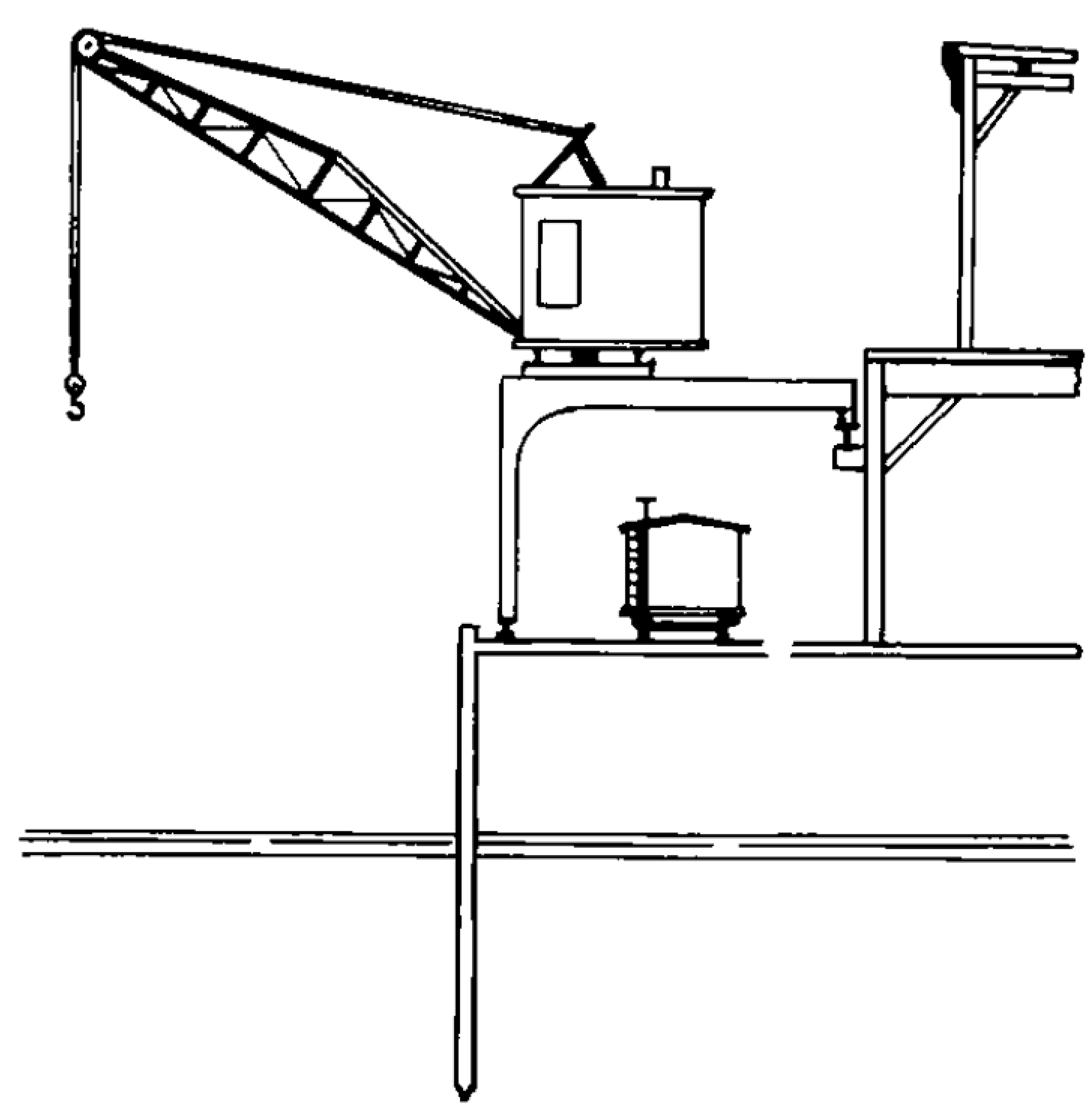
UNLOADING CARGO USING SHIP AND WHARF WINCH AND TEMPORARY BOOM *



LOADING CARGO USING SHIPS WINCH AND SKID *



LOADING CARGO USING DROP GANGWAY ESCALATOR AND TRUCKS *



GANTRY CRANE

*Adapted from Design of Harbor Structures by Spofford & Thorndike.

CORROSION OF METALS - GALVANIC ACTION

Two metals with a strong tendency to galvanic action should be used in juxtaposition with caution; particularly where moisture containing impurities may tend to complete a galvanic cycle.

GALVANIC SERIES*

Corroded end (anodic)

Magnesium
Aluminum
Duralumin

Zinc
Cadmium

Iron
Chromium-iron (active)
Chromium-nickel-iron (active)

Soft solder
Tin
Lead

Nickel
Brasses
Bronzes
Nickel-copper alloys
Copper

Chromium-iron (passive)
Chromium-nickel-iron (passive)

Silver solder

Silver
Gold
Platinum

Protected end (cathodic)

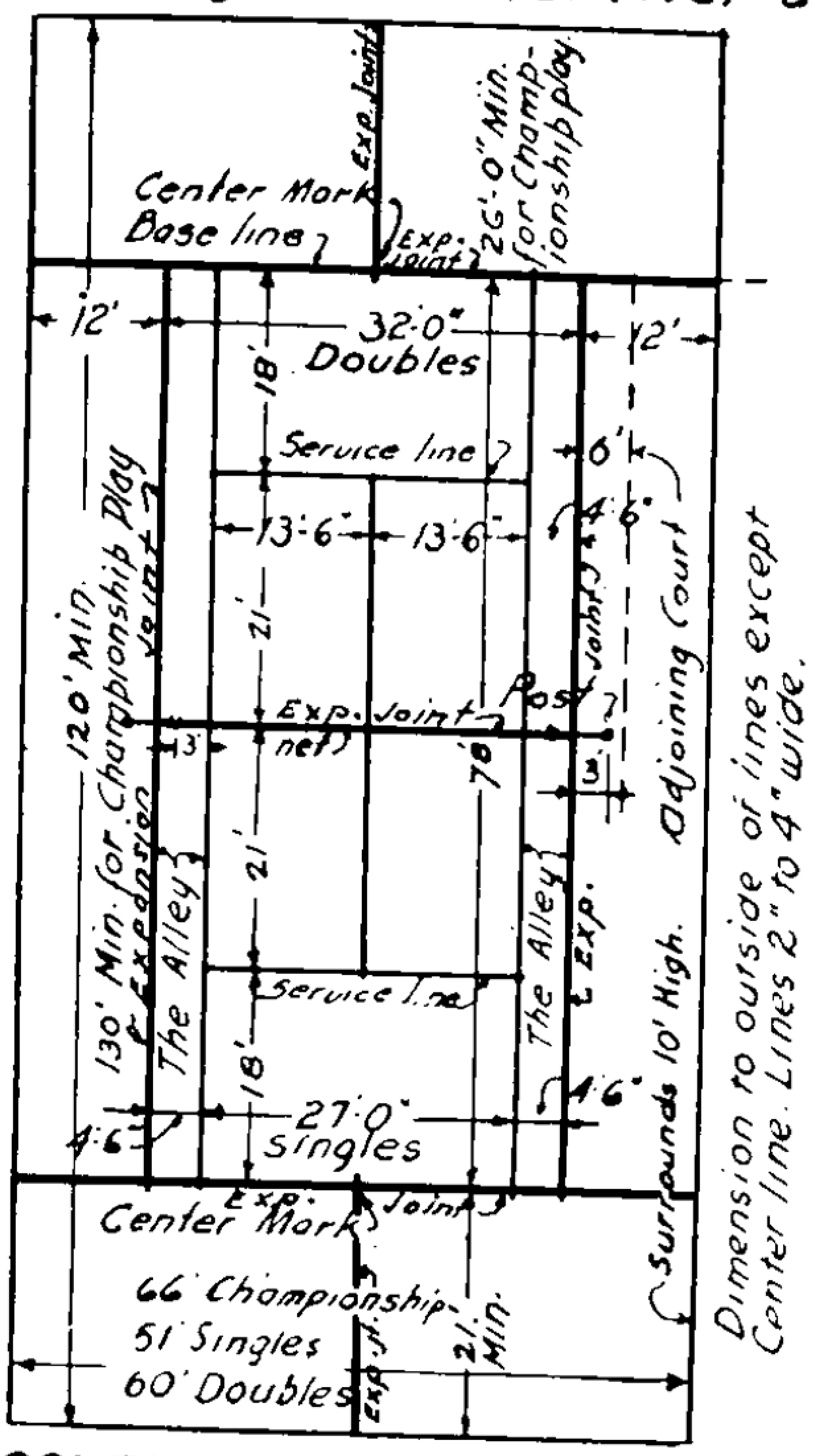
This series is built upon actual experience with corrosion and laboratory measurement. Metals grouped together have no strong tendency to produce galvanic corrosion on each other; connecting two metals distant on the list from each other tends to corrode the one higher in the list. Voltage figures are not given because these vary with every new corrosive condition. Relative positions of metals change in many cases but it is unusual for changes to occur across the spaces left blank. The chromium-irons and chromium-nickel-irons change position as indicated depending on oxidizing conditions, acidity, and chloride in solution. The series as it stands is correct for many common dilute water solutions such as sea water, weak acids and alkalies.

Aluminum should be used with caution in juxtaposition with cement or alkalies, particularly where moisture will occur. *See also page 4-85.*

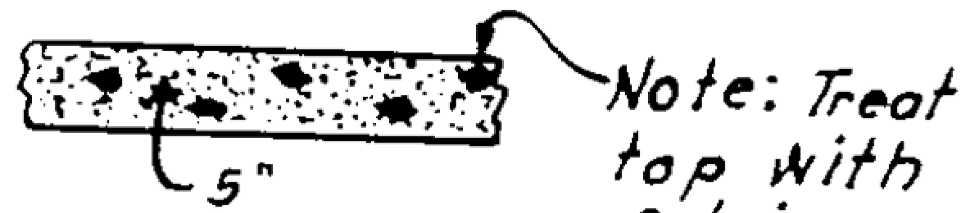
**Adapted from Corrosion Resistance of Metals and Alloys by McKay & Worthington, Reinhold Publishing Co.*

ATHLETIC FIELDS – DRAINAGE & DIMENSIONS

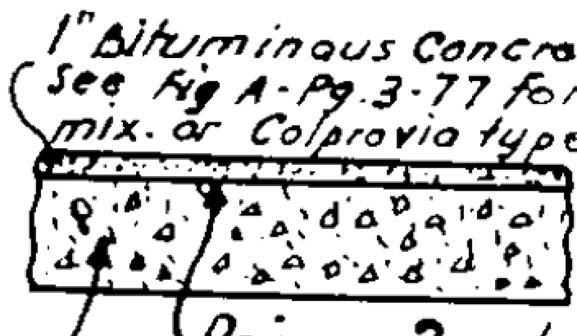
PURPOSE OF DRAINAGE: Surface slopes and drains to take off rainfall. Subdrains (or underdrains) to lower high ground water tables and to minimize frost action. Do not allow rainfall to run into underdrains. A porous fill is generally not subject to frost action, and use of such fill may eliminate need for underdrains. See Pg. 3·17 for further data on frost.

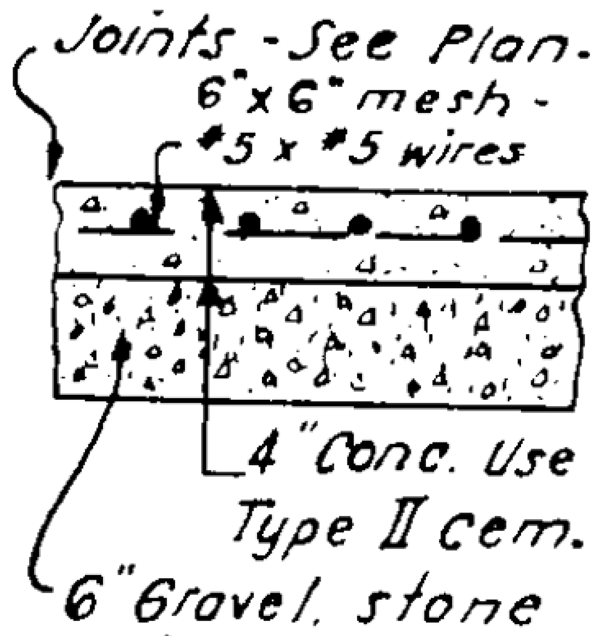


COURT DIMENSIONS *



Clay-Sand mixture. 1 part fine sand, 1 part clay. Materials to be dried, ground and mixed mechanically. Sand to be 85% between 100 & 200 mesh sieve.





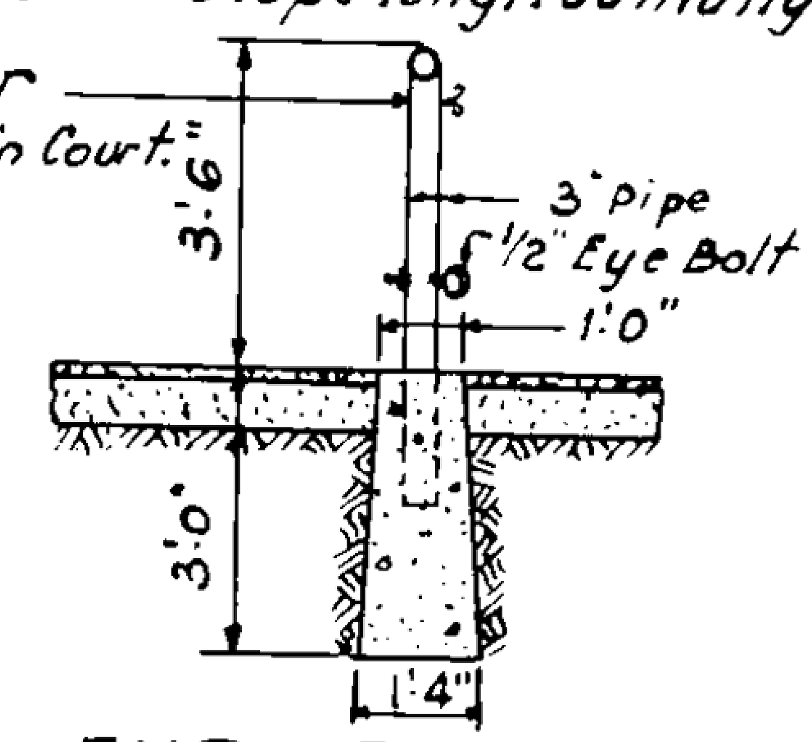
CLAY COURT — ASPHALT COURT — CONCRETE COURT

TENNIS COURT SECTIONS

Transverse slope - 2" for 56' width - Do not slope longitudinally.

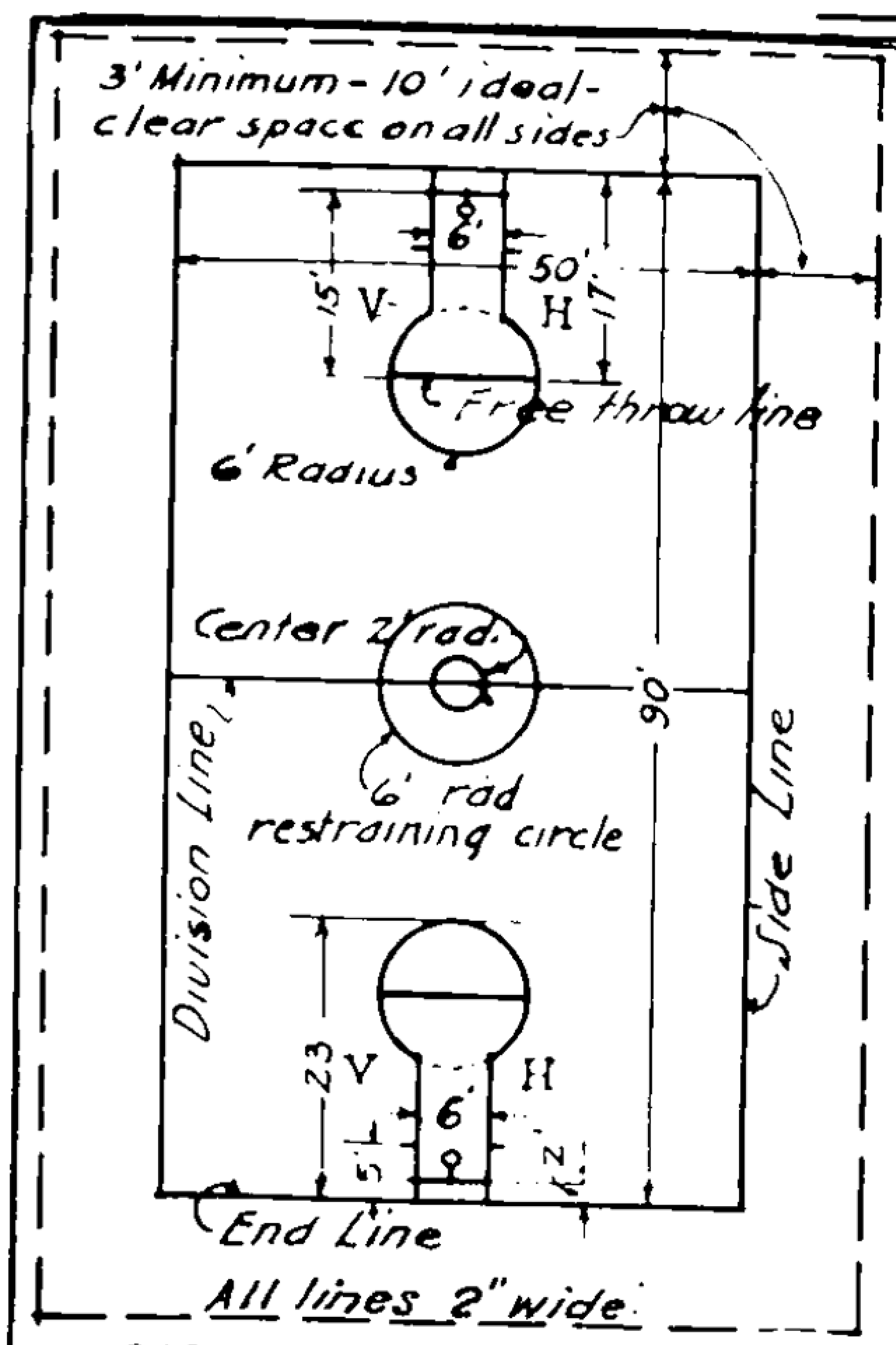
For courts played on more in P.M. than A.M. orient N.N.E. - S.S.W. in northern hemisphere.

ORIENTATION



END POST

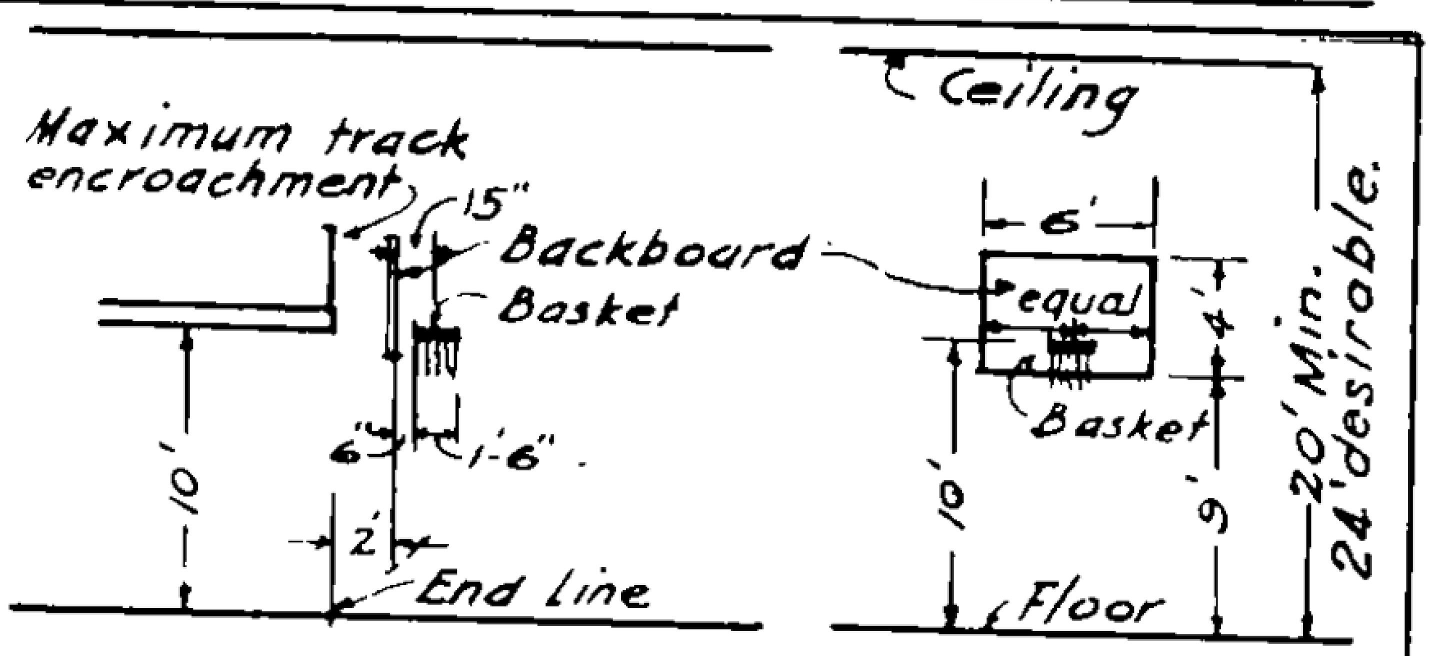
TENNIS COURT DETAILS



STANDARD COURT

Ideal Court Sizes:	College	90'x50'
	High Sch.	84'x50'
	Elem. Sch.	60'x35'
Min. Court dimensions		60'x35'
Max. Court dimensions		94'x50'
Junior High School		74'x42'

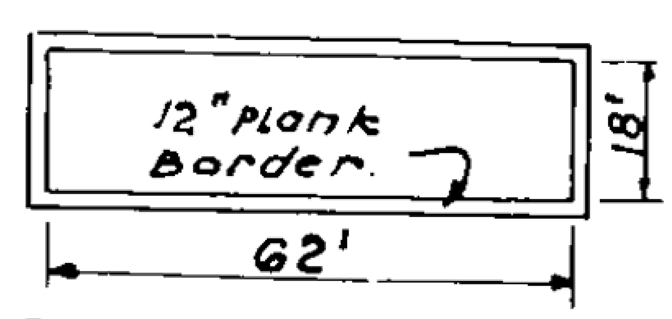
COURT DIMENSIONS



SECTION — ELEVATION

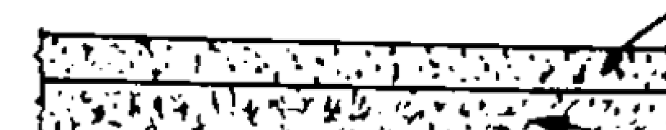
SHOWING BASKETS & ENCROACHMENTS

BASKETBALL *

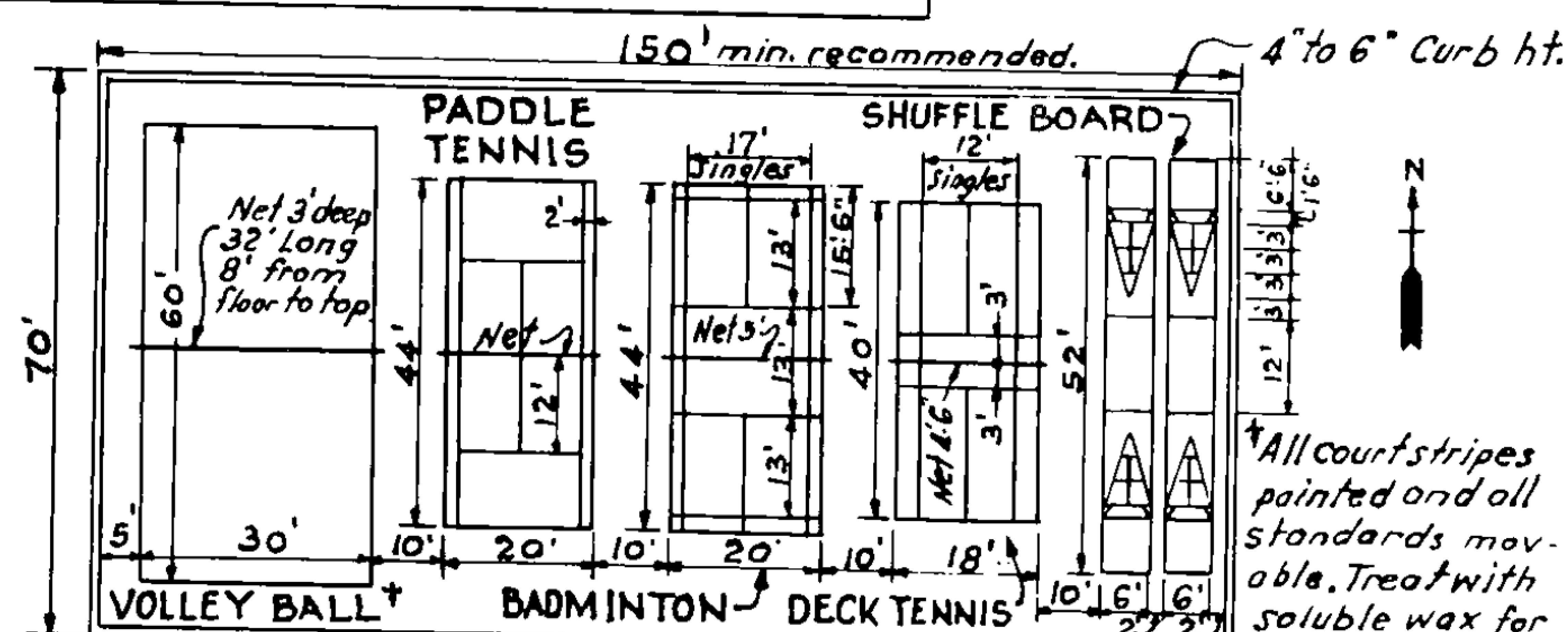


BOCCIE COURT

4" equal parts - Cinders & loam thru 1/4" screen.



6" Gravel, stone or Cinder base.



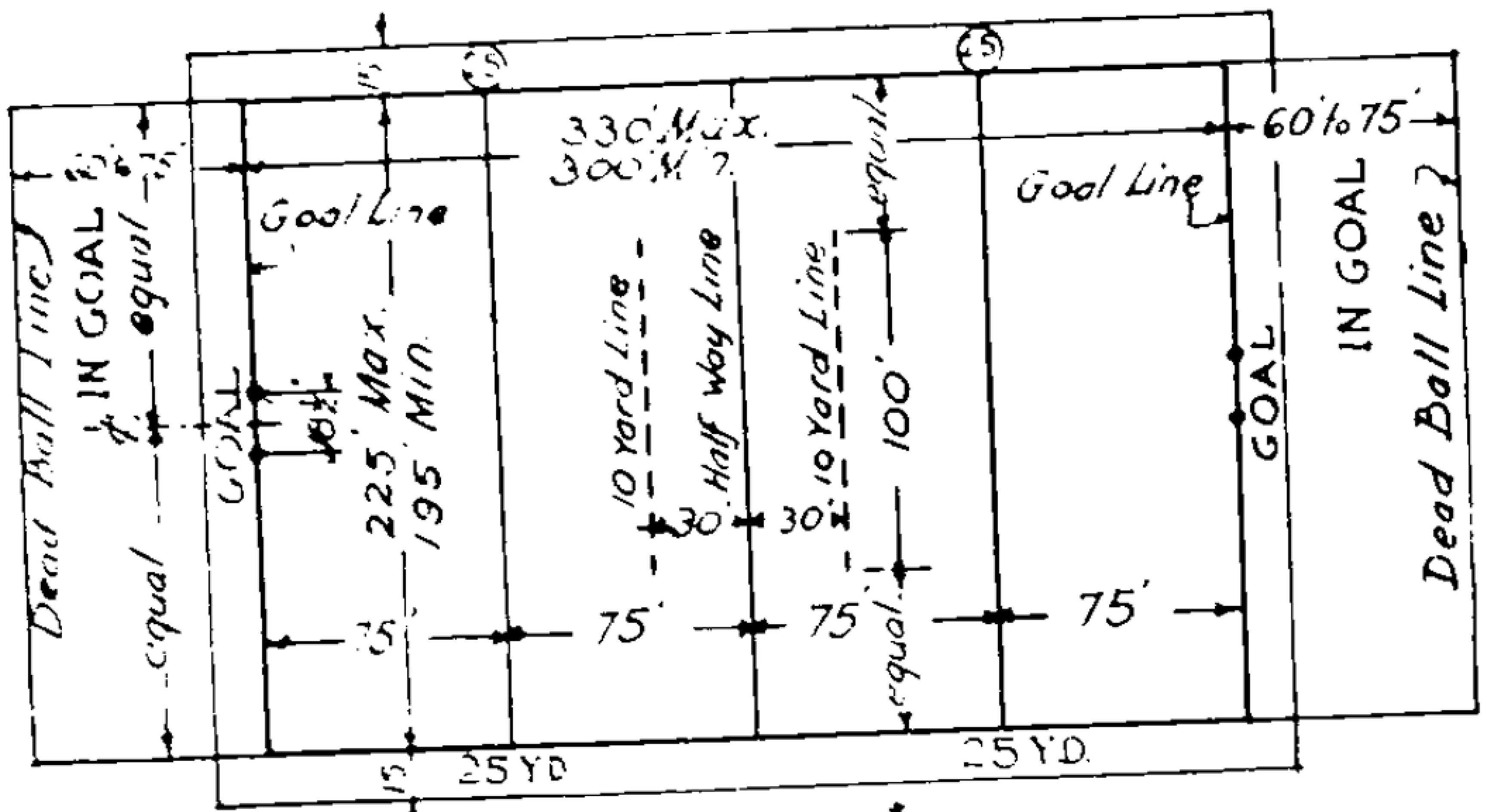
†All court stripes painted and all standards movable. Treat with soluble wax for dancing.

MULTIPLE USE AREA ††

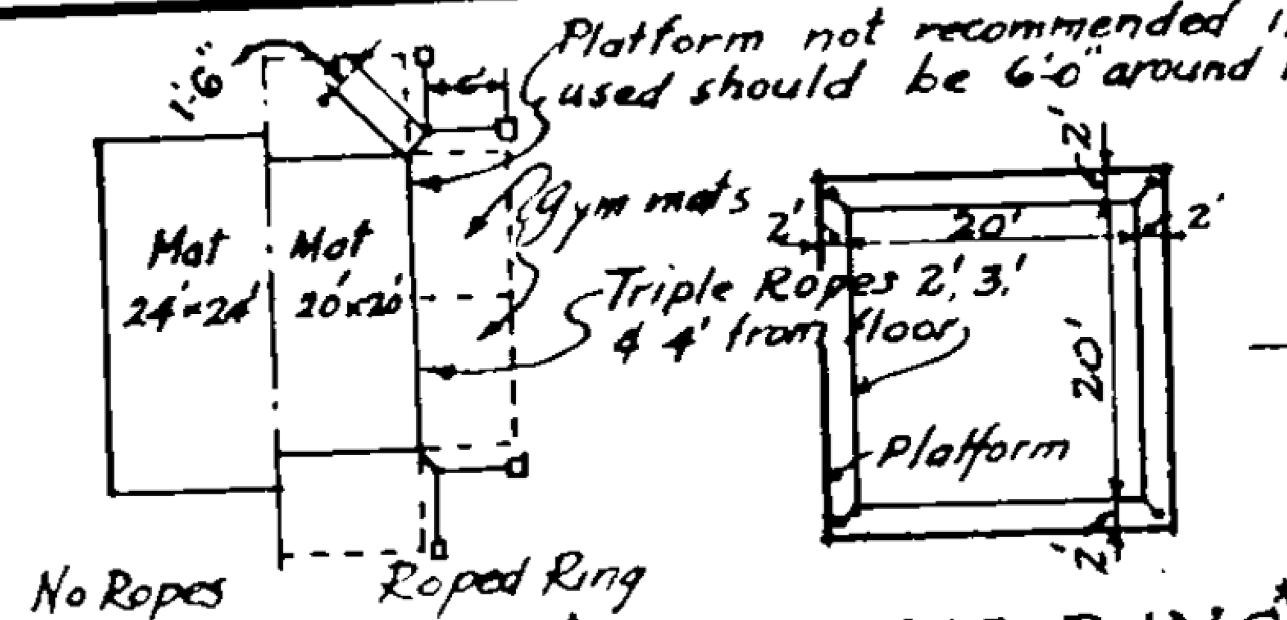
By using portable net standards, area can be cleared for various activities such as roller skating, square & social dancing. Curb allows area to be flooded for ice skating.

* Adapted from Arch. Graphic Stds. by Ramsey & Sleeper. †† Adapted from F. Ellwood Allen.

ATHLETIC FIELDS - DIMENSIONS - 1

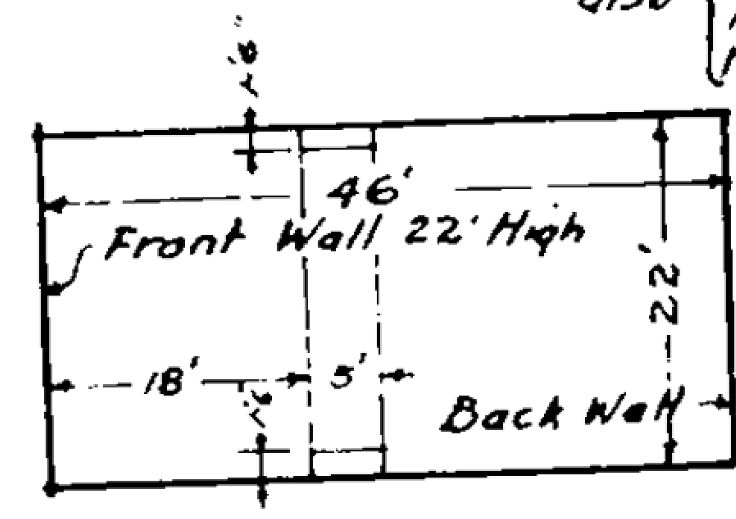


RUGBY*



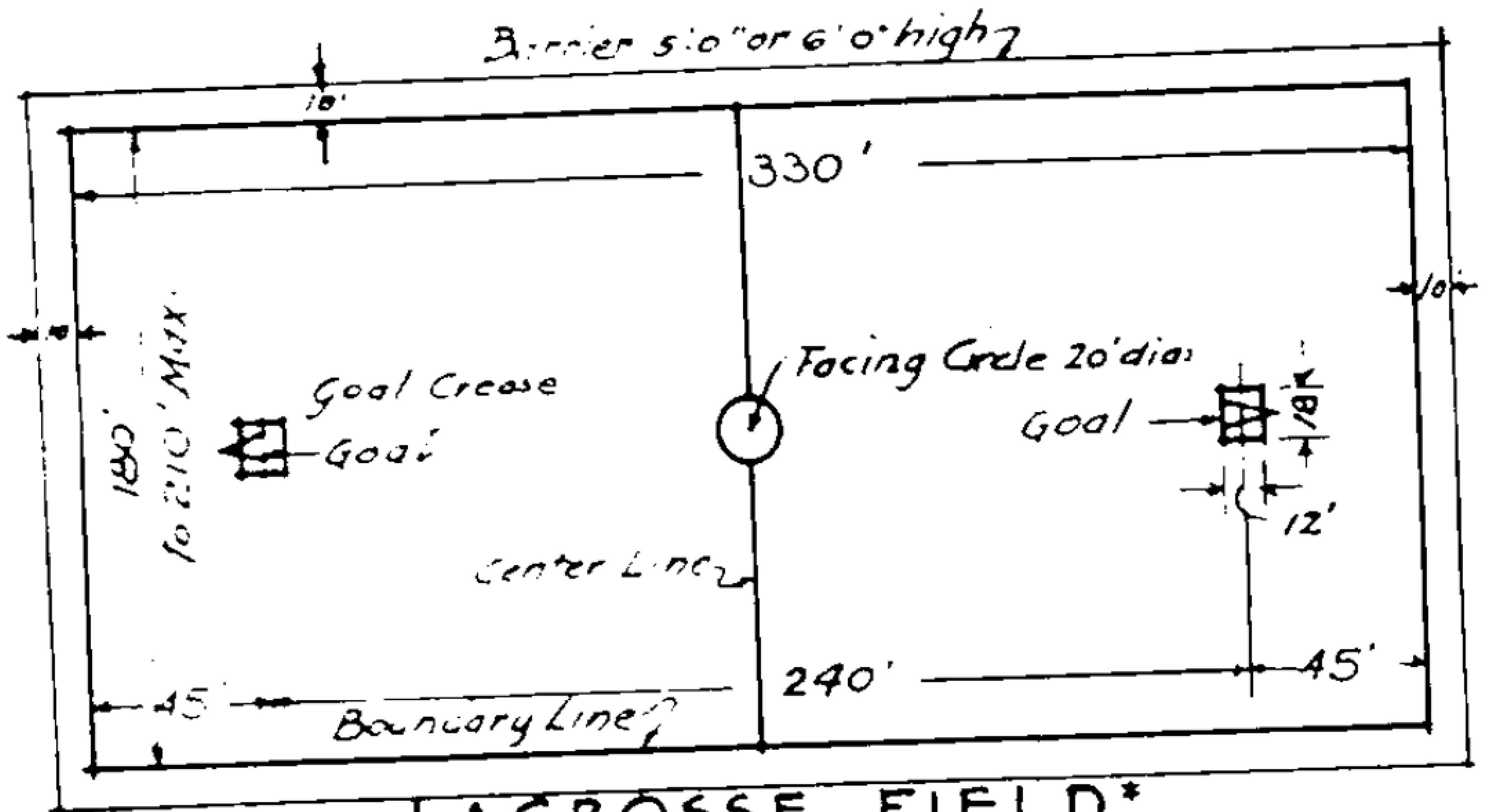
WRESTLING* BOXING RING*

also 16'x16', 18'x18', 14'x14'

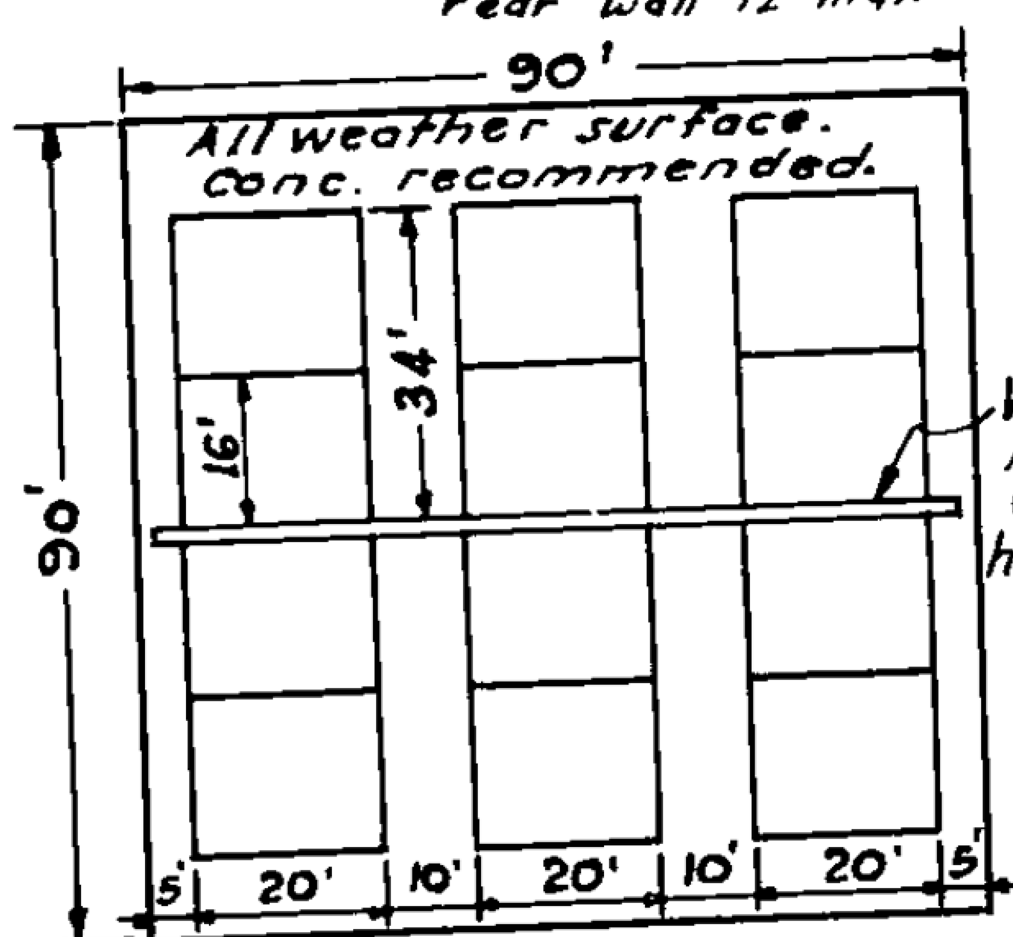


4 WALL HANDBALL COURT*

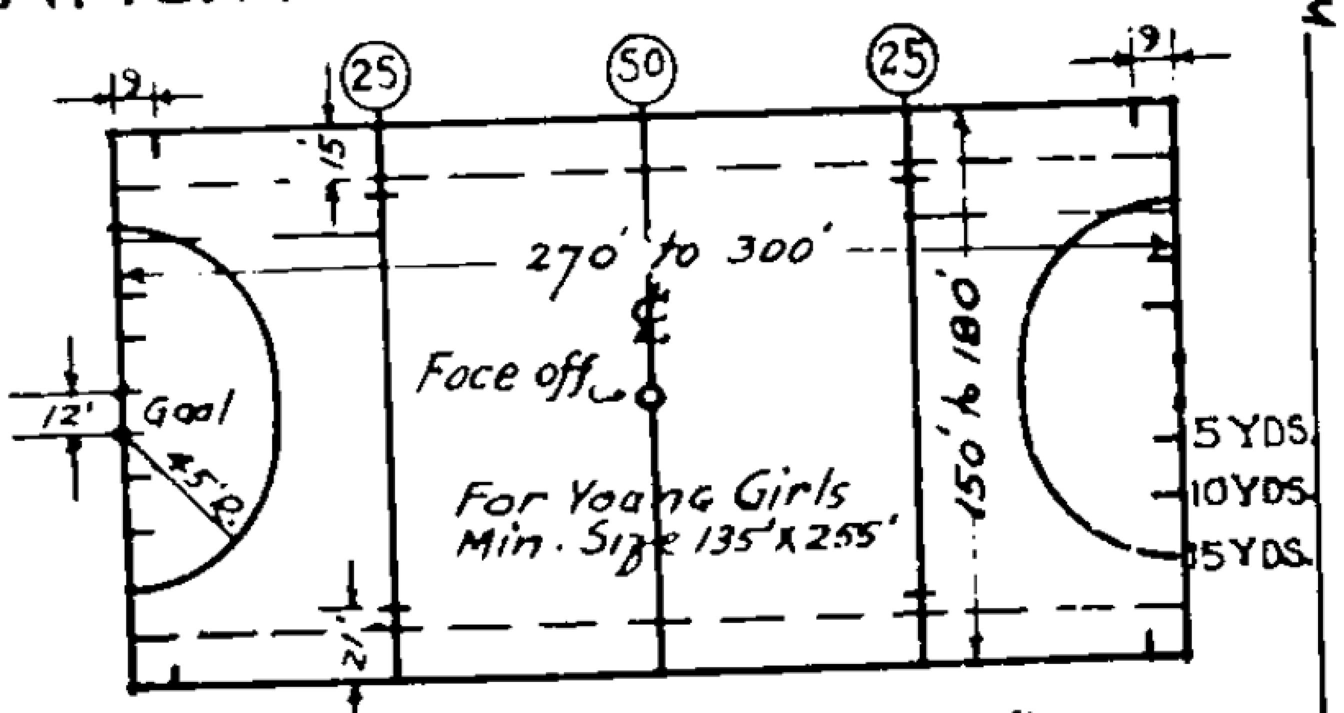
Hard ball court - 65'x25', front wall 30' high, rear wall 12' high



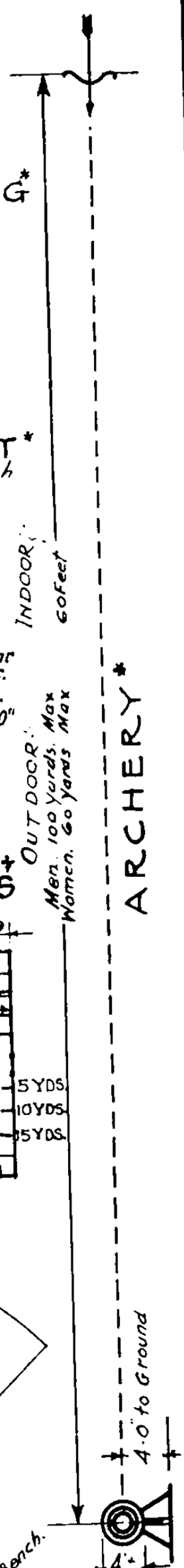
LACROSSE FIELD*

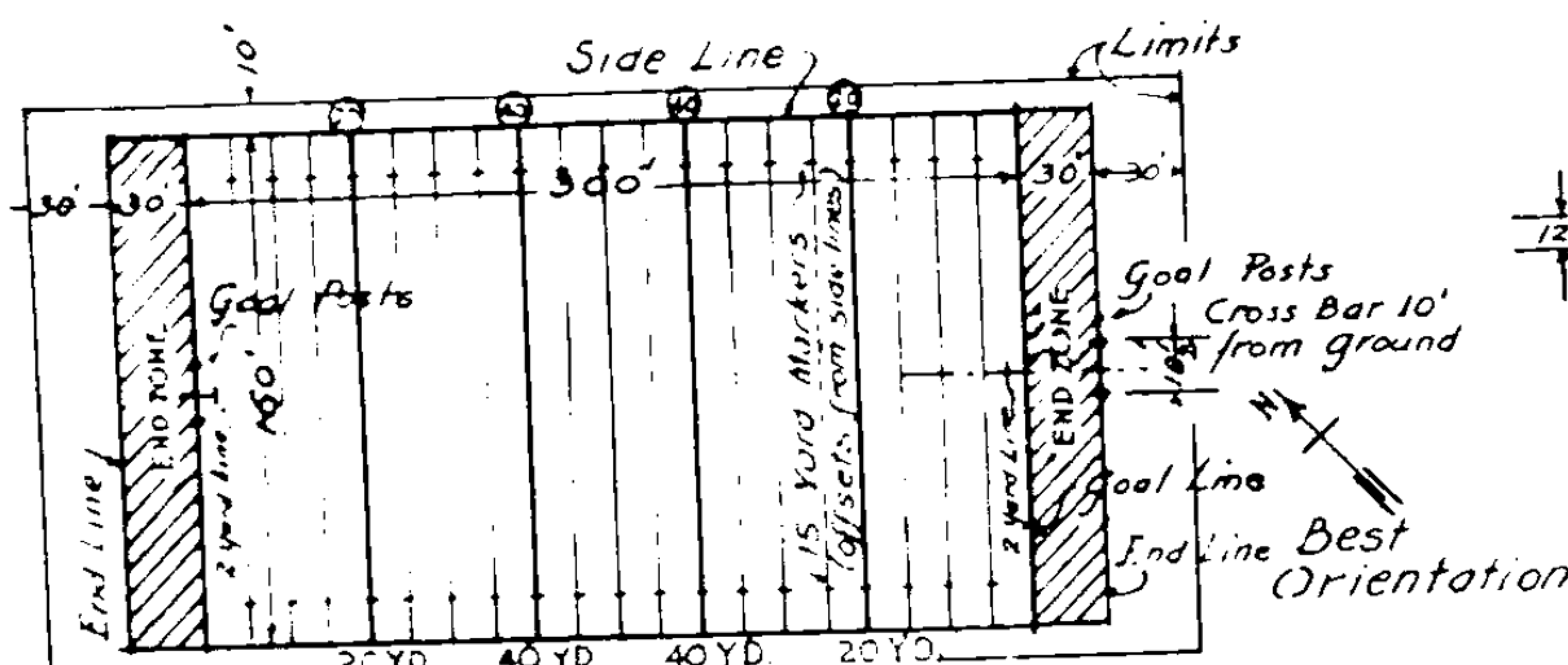


BATTERY OF 6 HANDBALL COURTS†



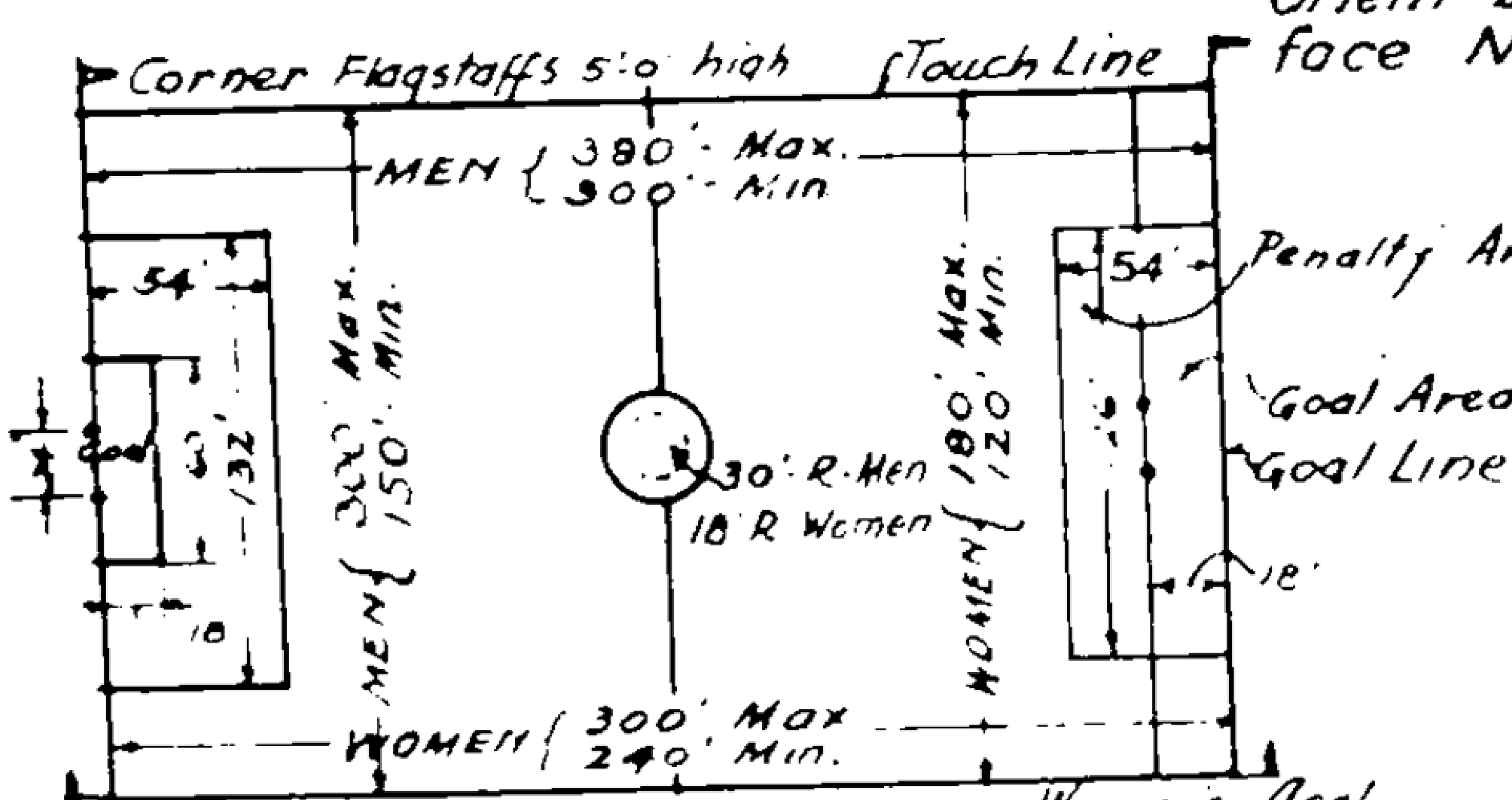
HOCKEY FIELD*



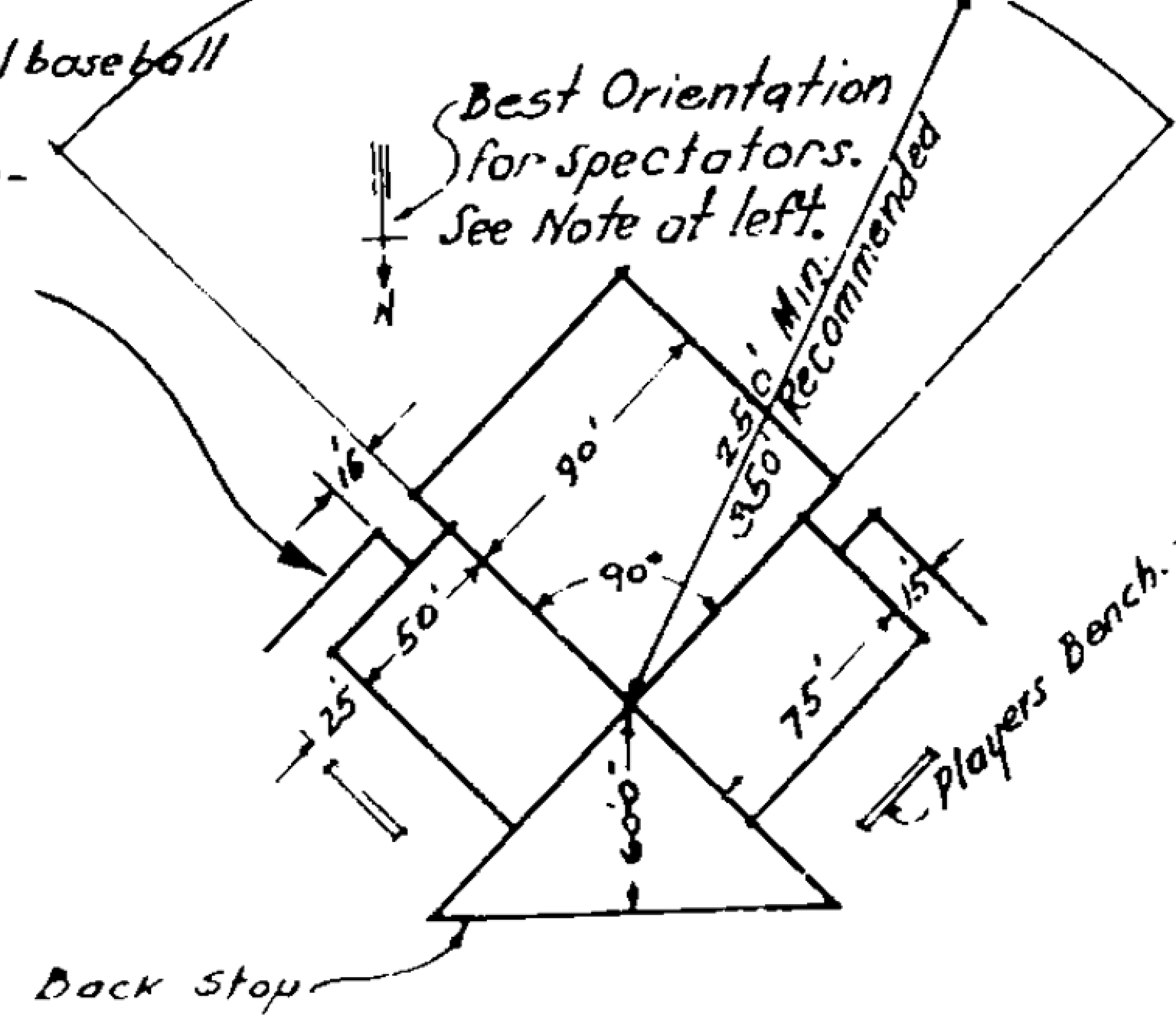


FOOTBALL FIELD*

NOTE: For municipal baseball fields - spectators not major factor - orient batter to face NE or SE.



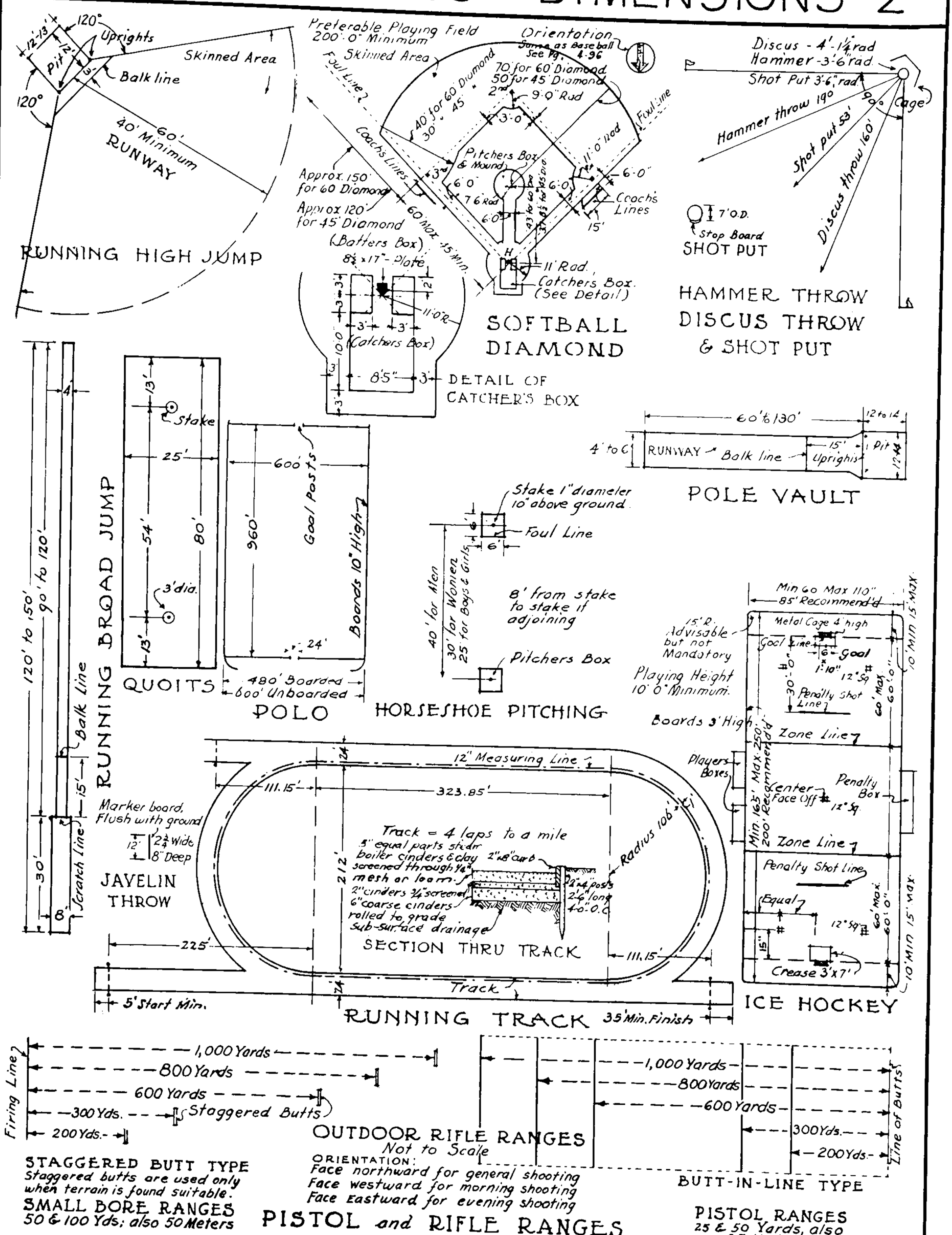
SOCCER FIELD*



BASEBALL FIELD*

*Adopted from Arch. Graphic stds. by Ramsey & Sleeper (Approved by Amer. Sports Publishg. Co. †Adopted from F. Ellwood Allen.

ATHLETIC FIELDS - DIMENSIONS*-2



* Adapted from Architectural Graphic Standards by Ramsey & Sleeper.

DRAINAGE — RUNOFF — 1

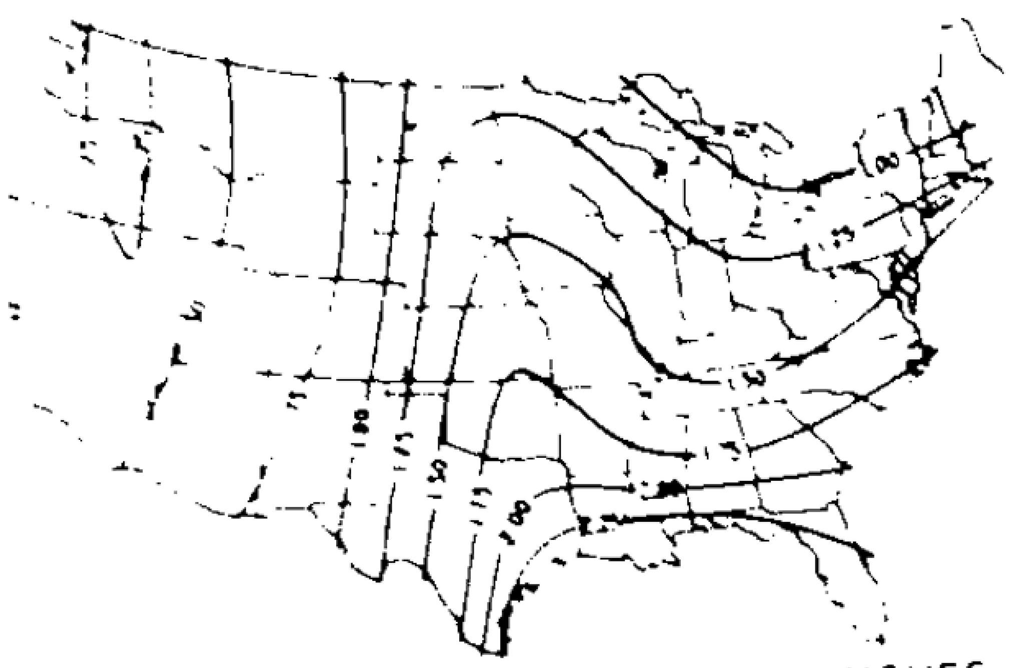


FIG. A. - ONE-HOUR RAINFALL, IN INCHES, TO BE EXPECTED ONCE IN 2 YEARS.

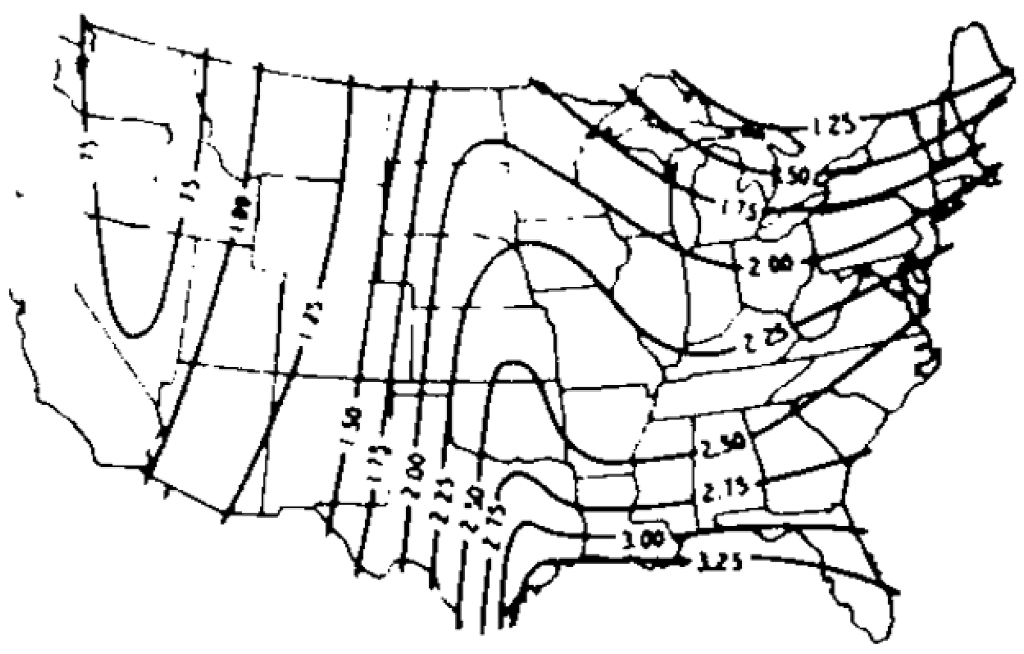


FIG. B. - ONE-HOUR RAINFALL, IN INCHES, TO BE EXPECTED ONCE IN 10 YEARS.

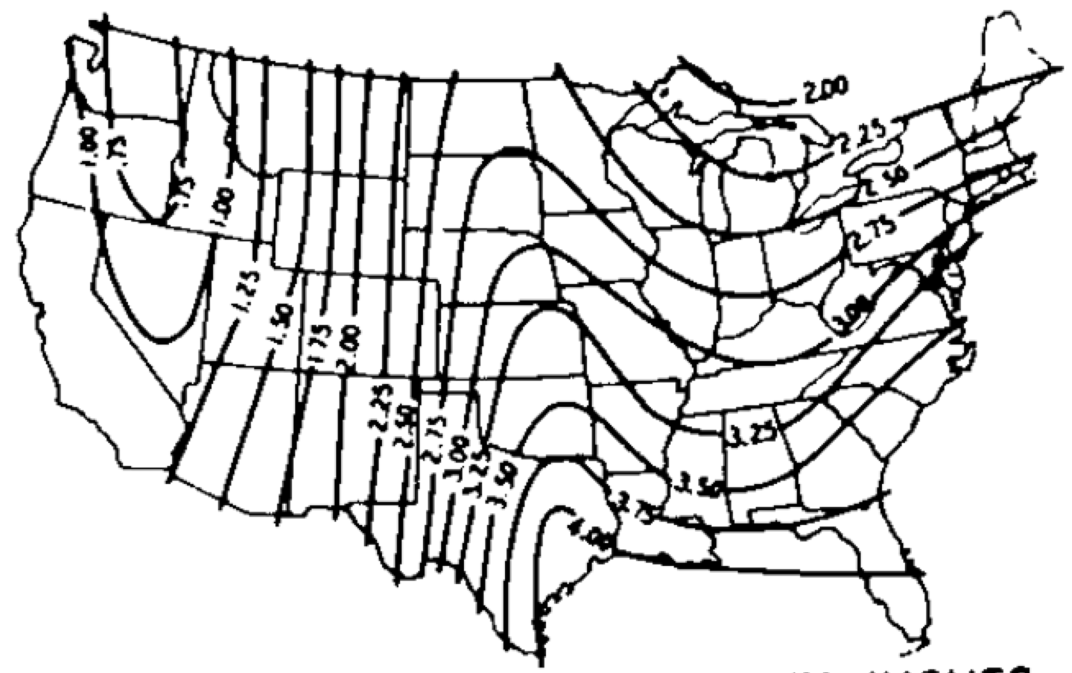


FIG. C. - ONE-HOUR RAINFALL, IN INCHES, TO BE EXPECTED ONCE IN 50 YEARS.

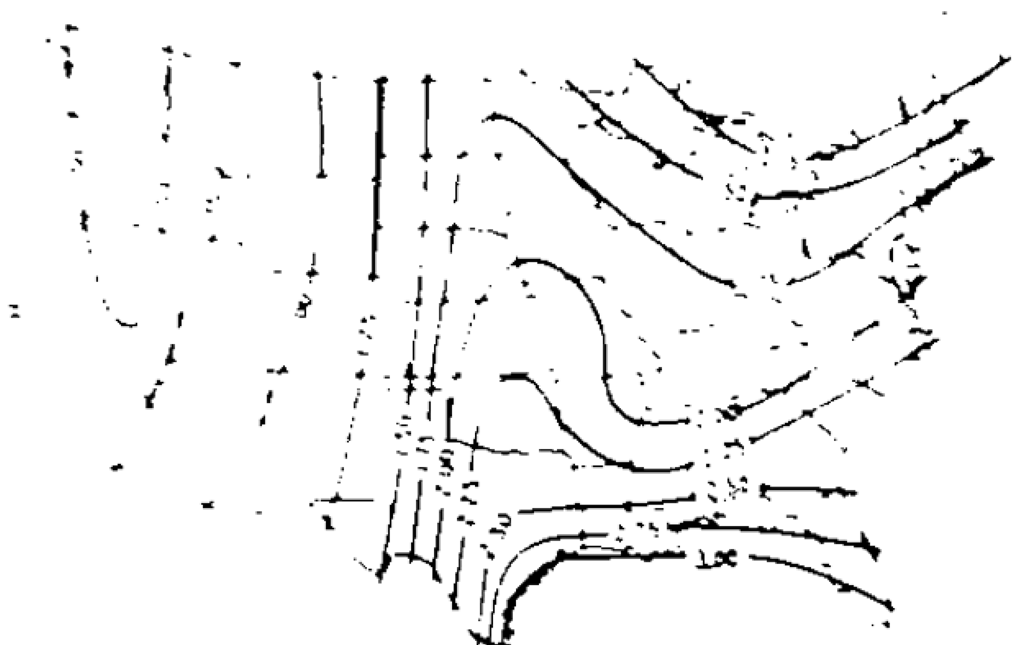


FIG. D. - ONE-HOUR RAINFALL, IN INCHES, TO BE EXPECTED ONCE IN 5 YEARS.

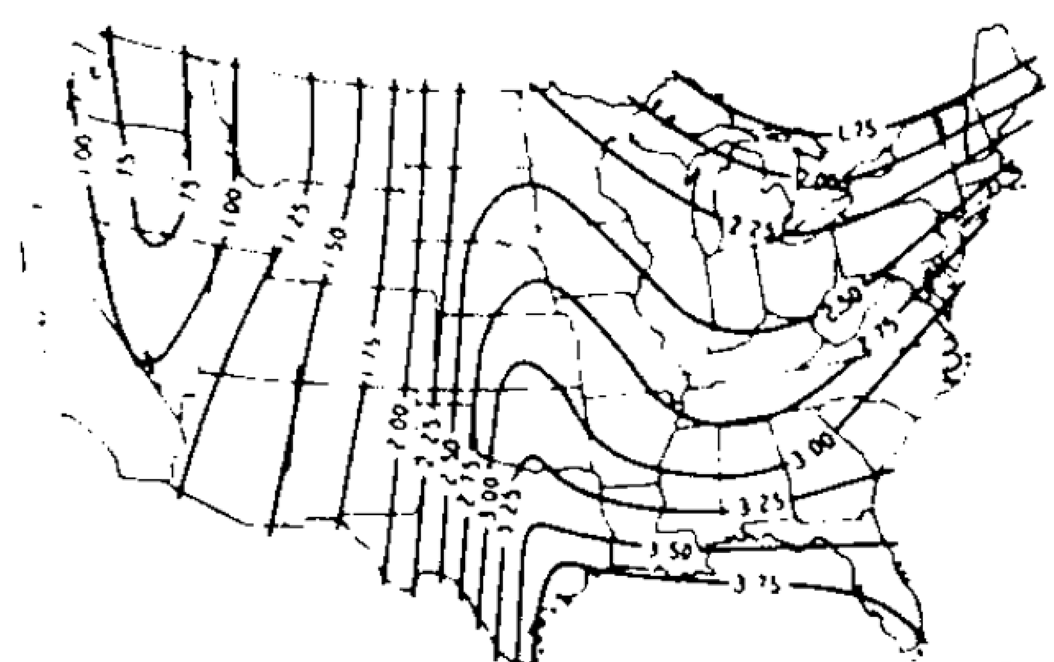


FIG. E. - ONE-HOUR RAINFALL, IN INCHES, TO BE EXPECTED ONCE IN 25 YEARS.

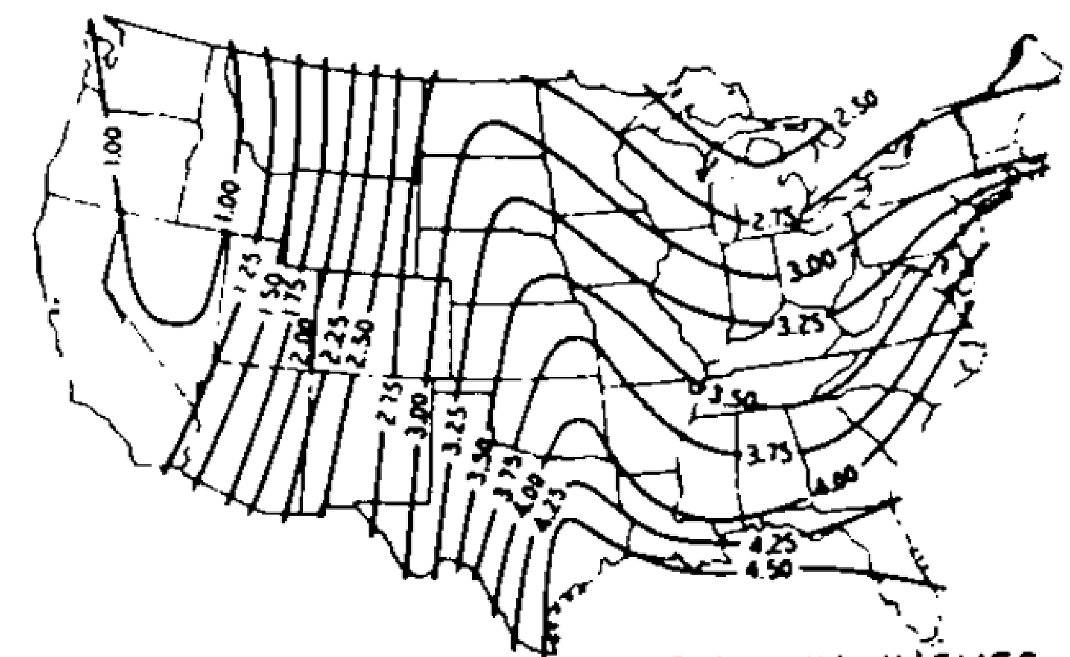


FIG. F. - ONE-HOUR RAINFALL, IN INCHES, TO BE EXPECTED ONCE IN 100 YEARS.

COMPUTATION OF i IN RATIONAL FORMULA.

EXAMPLE: Assume expectancy period = 5 years, See Fig. D, assume locality, find 1 hour intensity = 1.75 in. per hour.

FIG. G - INTENSITY EXPECTATION FOR ONE-HOUR RAINFALL.*

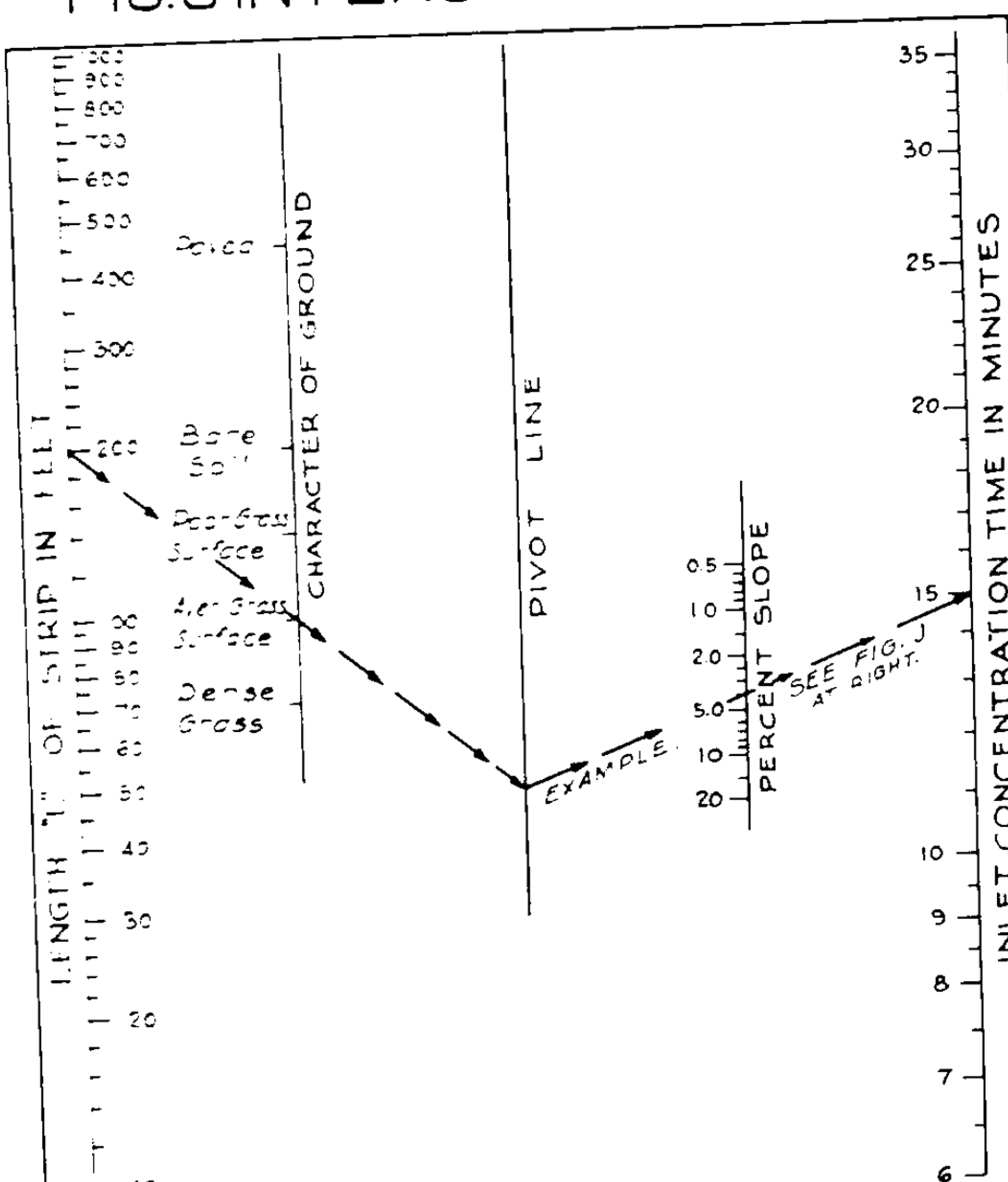


FIG. H - OVERLAND FLOW TIME.

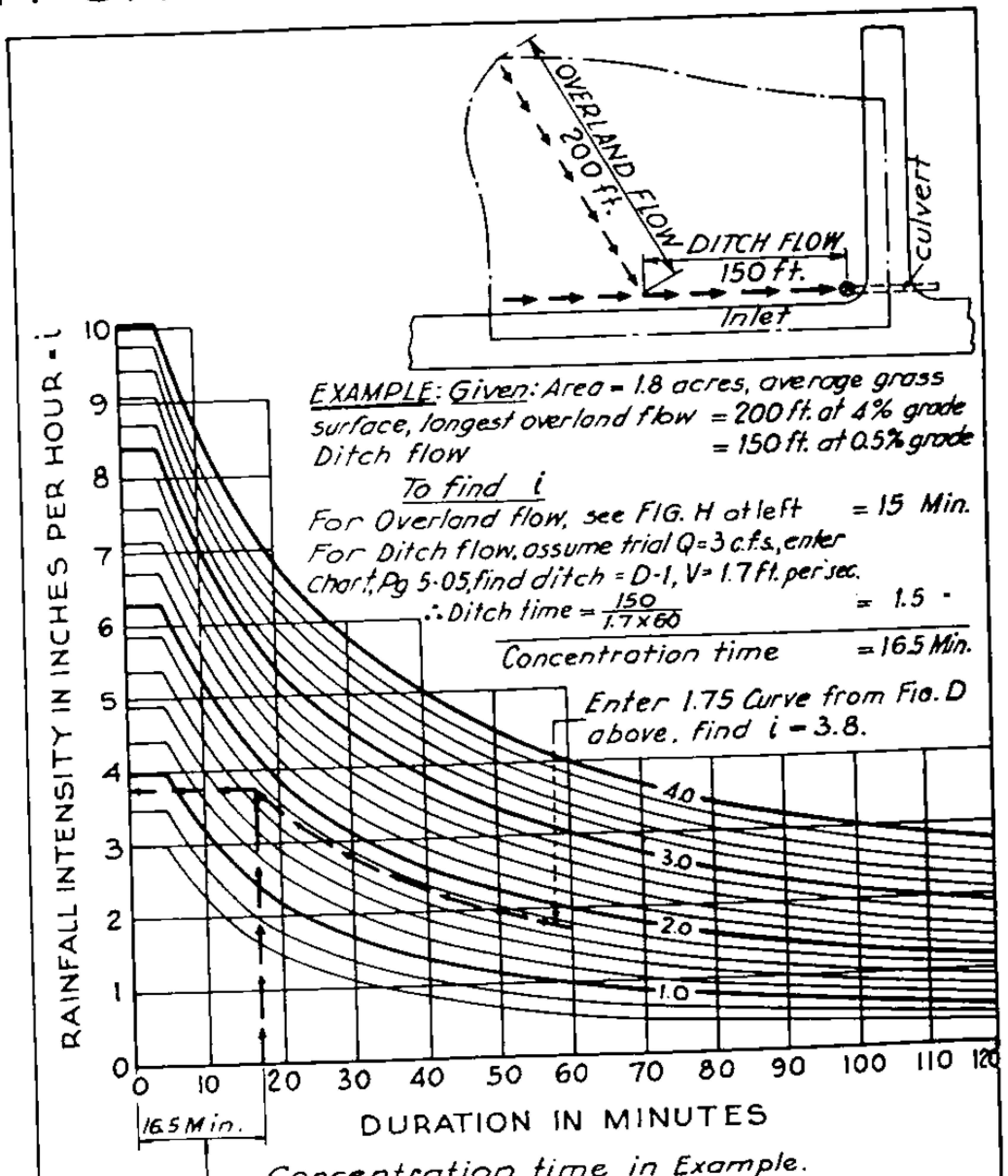


FIG. J - VALUES OF i RAINFALL INTENSITY-DURATION.+

*Reproduced from Miscellaneous Publication No. 204, U.S. Dept. of Agriculture by David L. Yarnell.

+ Adapted from Engineering Manual of the War Department, July 1942.

DRAINAGE — RUNOFF-2

Q=Aci RATIONAL FORMULA (Logical approach).

Q = RUNOFF = Peak discharge of watershed in cubic feet per second (c.f.s.) due to maximum storm assumed. See Figs. A to F, Pg. 5-00 (Usually 10 – 25 years).
A = Area of watershed in acres.
C = Coefficient of runoff, Table B below (Measure of losses due to infiltration, etc.).
i = Intensity of rainfall in inches per hour based on concentration time. See Pg. 5-00.
Concentration time = time required for rain falling at most remote point to reach discharge point. Concentration time may include Overland flow time, Fig. H, Pg. 5-00, and Channel flow time, Pg. 5-04, 5-05, 5-27 and 5-29.

TABLE A-COMPUTATION FORM FOR RATIONAL FORMULA.

LOCATION			A			TIME OF FLOW, MIN.				DESIGN					PROFILE				
STREET	FROM	TO	INCREMENT	TOTAL	C	TO INLET	IN CHANNEL	i *	Q c.f.s.	CHANNEL OR PIPE SIZE	SLOPE ft. per ft.	n	CAPACITY FULL c.f.s.	V ft. per Sec.	LENGTH ft.	FALL ft.	OTHER LOSSES ft. †	INV. ELEV. UPPER END	INV. ELEV. LOWER END
FIRST ST.	A	B	1.8	1.8	.44	16.5	0.3	3.8	3.0	15"	.008	.015	4.6	3.9	60	0.48	0	82.00	81.52
MAIN RD.	B	C	1.9	3.7	.50		2.5	3.7	6.8	D-2	.011	.030	12.0	2.8	420	4.62	0	81.52	76.90
" "	C	D	2.0	5.7	.50		1.8	3.5	10.0	21"	.007	.015	11.1	4.5	480	3.36	2.20	74.70	70.34

*Note that the sequence of design as in example, Fig. J, Pg. 5-00, involves trial assumptions in determining i.
†Fall in manhole.

TABLE B – VALUES OF $C = \frac{RUNOFF}{RAINFALL}$

SURFACES			VALUE PROPOSED MIN.	VALUE PROPOSED MAX.	VALUE BY OTHER AUTHORITY MIN.	VALUE BY OTHER AUTHORITY MAX.	
ROOFS, slag to metal.			0.90	1.00	0.70	0.95	①
PAVEMENTS	Concrete or Asphalt.		0.90	1.00	0.95	1.00	③
	Bituminous Macadam, open and closed type.		0.70	0.90	0.70	0.90	③
	Gravel, from clean and loose to clayey and compact.		0.25	0.70	0.15	0.30	①
R.R. YARDS			0.10	0.30	0.10	0.30	①
EARTH SURFACES	SAND, from uniform grain size, no fines, to well graded, some clay or silt.	Bare	0.15	0.50	0.01	0.55	④
		Light Vegetation	0.10	0.40	0.01	0.55	④
		Dense Vegetation	0.05	0.30	0.01	0.55	④
	LOAM, from sandy or gravelly to clayey.	Bare	0.20	0.60			
		Light Vegetation	0.10	0.45			
		Dense Vegetation	0.05	0.35			
	GRAVEL, from clean gravel and gravel sand mixtures, no silt or clay to high clay or silt content.	Bare	0.25	0.65			
		Light Vegetation	0.15	0.50			
		Dense Vegetation	0.10	0.40			
	CLAY, from coarse sandy or silty to pure colloidal clays.	Bare	0.30	0.75	0.10	0.70	④
		Light Vegetation	0.20	0.60	0.10	0.70	④
		Dense Vegetation	0.15	0.50	0.10	0.70	④
COMPOSITE AREAS	City, business areas.		0.60	0.75	0.60	0.95	⑤
	City, dense residential areas, vary as to soil and vegetation.		0.50	0.65	0.30	0.60	⑤
	Suburban residential areas. " " "		0.35	0.55	0.25	0.40	⑤
	Rural Districts, " " "		0.10	0.25	0.10	0.25	②
	Parks, Golf Courses, etc., " " "		0.10	0.35	0.05	0.25	①

NOTE: Values of "C" for earth surfaces are further varied by degree of saturation, compaction, surface irregularity and slope, by character of subsoil, and by presence of frost or glazed snow or ice.

① Bryant & Kuichling, Report, Back Bay Sewerage District, Boston, 1909.
② Metcalf and Eddy, American Sewerage Practice, 1928. Mc Graw-Hill.
③ Used by City of Boston, reported by Metcalf & Eddy.
④ Used by City of Detroit, reported by Metcalf & Eddy.
⑤ L.C. Urquhart, Civil Engineering Handbook, 1940: Mc Graw-Hill.

DRAINAGE — RUNOFF-3

$Q = Aci\sqrt[5]{S/A}$ Mc.MATH FORMULA (Empirical approach).

Q = Runoff in c.f.s.
A = Area of watershed in acres.
c = Coefficient of runoff, see Table B-Pg. 5-01.
*i = Intensity of rainfall in inches per hour for a 20 min. storm**
S = Average slope of watershed in feet per thousand.

EXAMPLE: Given: Area = 12 acres, suburban residential area, clay-loam, light vegetation. Average slope = 25 feet per 1000. Locality southern Ohio. Required to find Q. C = 0.50 from Table B-Pg. 5-01. To find i, enter Fig. D-Pg. 5-00, find intensity for one hour = 1.75; enter Fig. J. Pg. 5-00 on 1.75 curve and find i = 3.4 for 20 min. duration.

$\therefore\ Q = 12 \times 0.50 \times 3.4\sqrt[5]{25/12} = 20.4\sqrt[5]{2.1}$ $\quad (\sqrt[5]{2.1} = 1.16$, see Table A below)

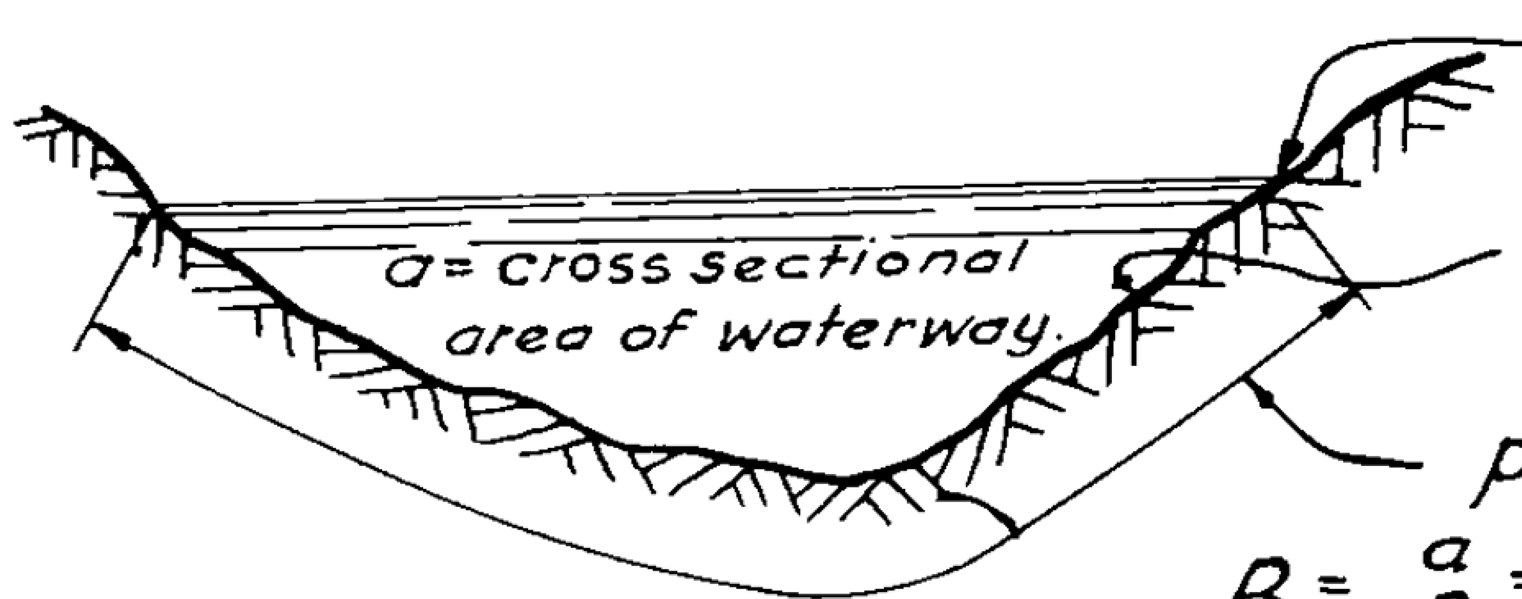
$= 20.4 \times 1.16 = 23.7$ c.f.s.

**Recommended.*

TABLE A-FIFTH ROOTS.

NO.	ROOT	NO.	ROOT	NO.	ROOT	NO.	ROOT	NO.	ROOT	NO.	ROOT
.031	.50	.371	.82	1.22	1.04	4.65	1.36	13.4	1.68	32.0	2.00
.038	.52	.418	.84	1.34	1.06	5.00	1.38	14.2	1.70	36.2	2.05
.046	.54	.470	.86	1.47	1.08	5.38	1.40	15.1	1.72	40.8	2.10
.055	.56	.528	.88	1.61	1.10	5.77	1.42	15.9	1.74	45.9	2.15
.066	.58	.590	.90	1.76	1.12	6.19	1.44	16.9	1.76	51.5	2.20
.078	.60	.624	.91	1.93	1.14	6.63	1.46	17.9	1.78	57.7	2.25
.092	.62	.659	.92	2.10	1.16	7.10	1.48	18.9	1.80	64.4	2.30
.107	.64	.696	.93	2.29	1.18	7.59	1.50	20.0	1.82	71.7	2.35
.125	.66	.734	.94	2.49	1.20	8.11	1.52	21.1	1.84	79.6	2.40
.145	.68	.774	.95	2.70	1.22	8.66	1.54	22.3	1.86	88.3	2.45
.168	.70	.815	.96	2.93	1.24	9.24	1.56	23.5	1.88	97.7	2.50
.193	.72	.859	.97	3.18	1.26	9.85	1.58	24.8	1.90	108.	2.55
.222	.74	.904	.98	3.44	1.28	10.5	1.60	26.1	1.92	119.	2.60
.254	.76	.951	.99	3.71	1.30	11.2	1.62	27.5	1.94	131.	2.65
.289	.78	1.00	1.00	4.01	1.32	11.9	1.64	28.9	1.96	143.	2.70
.328	.80	1.10	1.02	4.32	1.34	12.6	1.66	30.4	1.98	157.	2.75

DETERMINATION OF RUNOFF (Q) FROM SURVEY OF EXISTING CHANNEL.



Highwater level from observed marks or records.

n = Coefficient of roughness of existing surface, see Pg. 5-26.

p = wetted perimeter, measured

$R = \frac{a}{p}$ = *Hydraulic radius.*

S = Slope of Hydraulic Gradient (water surface) in feet per ft. for reach of channel through cross-section.

FIG. B-EXISTING SECTION AT SITE OF PROPOSED BRIDGE OR CULVERT.

Determine Q by Manning or Kutter Formula, see Pg. 5-27 & Pg. 5-29.

DRAINAGE - RUNOFF-4

$a = C\sqrt[4]{A^3}$ - TALBOT'S FORMULA - (APPROXIMATE APPROACH)

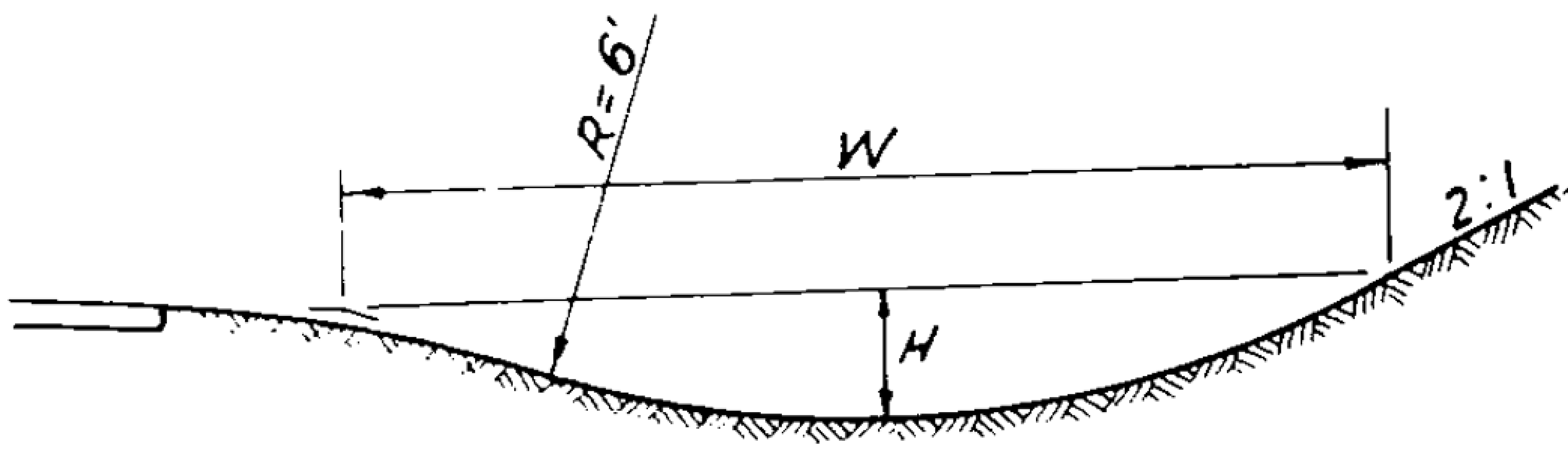
a = Required section of waterway in square feet.
A = Drainage area in acres; C = Talbot's coefficient.

DRAINAGE AREA		VALUES OF "a"						
		MOUNTAINOUS	HILLY LAND		ROLLING LAND		FLAT LAND	
Acres	Square miles	ASSUME C = 1.00	C = 0.80	C = 0.60	C = 0.50	C = 0.40	C = 0.30	C = 0.20
1	0.0016	1.0	0.8	0.6	0.5	0.4	0.3	0.2
2	0.0031	1.7	1.4	1.0	.8	.7	.5	.3
4	0.0062	2.8	2.2	1.7	1.4	1.1	.8	.6
6	0.0094	3.8	3.0	2.3	1.9	1.5	1.1	.8
8	0.0125	4.8	3.8	2.9	2.4	1.9	1.4	1.0
10	0.016	5.6	4.5	3.4	2.8	2.2	1.7	1.2
15	0.023	7.6	6.1	4.6	3.8	3.0	2.3	1.5
20	0.031	9.5	7.6	5.7	4.7	3.8	2.8	1.9
30	0.047	12.8	10.2	7.7	6.4	5.1	3.8	2.6
40	0.062	15.9	12.7	9.5	8	6.4	4.8	3.2
60	0.094	22	17.6	13	11	8.8	6.6	4.4
ASSUME 80	0.125	27	21.6	16	13	10.8	8.1	5.4
100	0.156	32	25.6	19	16	12.8	9.6	6.4
150	0.234	43	34.4	26	21	17.2	12.9	8.6
200	0.312	53	42.4	32	27	21.2	15.9	10.6
250	0.39	63	50	38	31	25	19	13
300	0.47	72	58	43	36	29	22	14
400	0.62	89	71	53	45	36	27	18
500	0.78	106	85	64	53	42	32	21
600	0.94	121	97	73	61	48	36	24
800	1.25	150	120	90	75	60	45	30
1,000	1.56	178	142	107	89	71	53	36
1,500	2.34	241	193	145	121	96	72	48
2,000	3.12	299	239	179	149	120	90	60
2,500	3.91	354	283	212	177	142	106	71
3,000	4.7	405	324	243	203	162	122	81
4,000	6.2	503	402	302	252	202	151	101
5,000	7.8	595	476	357	297	238	179	119
6,000	9.4	682	546	409	341	273	205	136
8,000	12.5	846	677	508	423	338	254	169
10,000	15.6	1,000	800	600	500	400	300	200
25,000	39.1	1,988	1,590	1,193	994	795	596	398
50,000	78	3,344	2,675	2,006	1,672	1,338	1,003	669
100,000	156	5,623	4,498	3,374	2,812	2,249	1,687	1,125
200,000	312	9,457	7,566	5,674	4,728	3,783	2,837	1,891
400,000	625	15,905	12,724	9,543	7,952	6,362	4,772	3,181

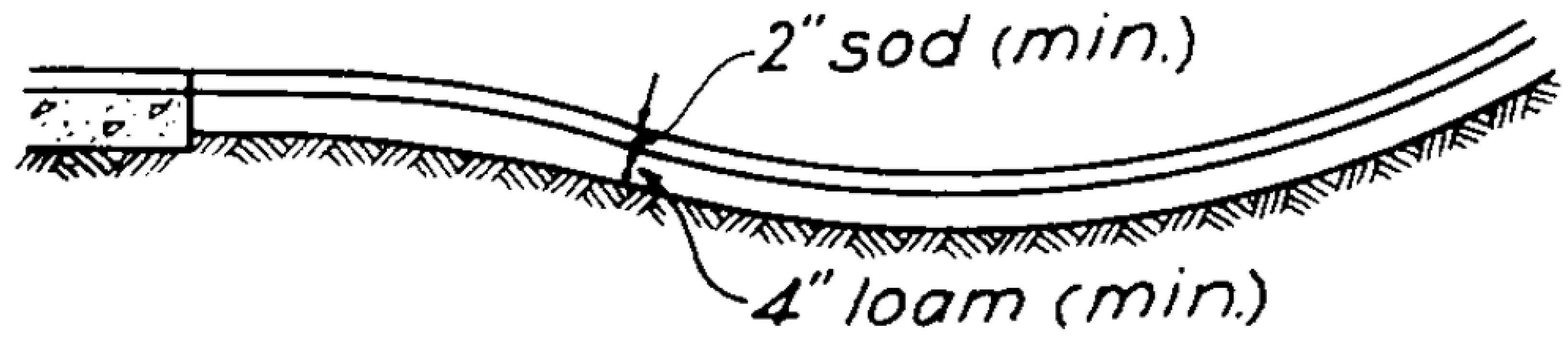
From Manual of Instructions, Surveys and Plans, Division of Highways, California Dept of Public Works, 1931.

Adapted from Urquhart, Civil Engineering Handbook, McGraw-Hill.

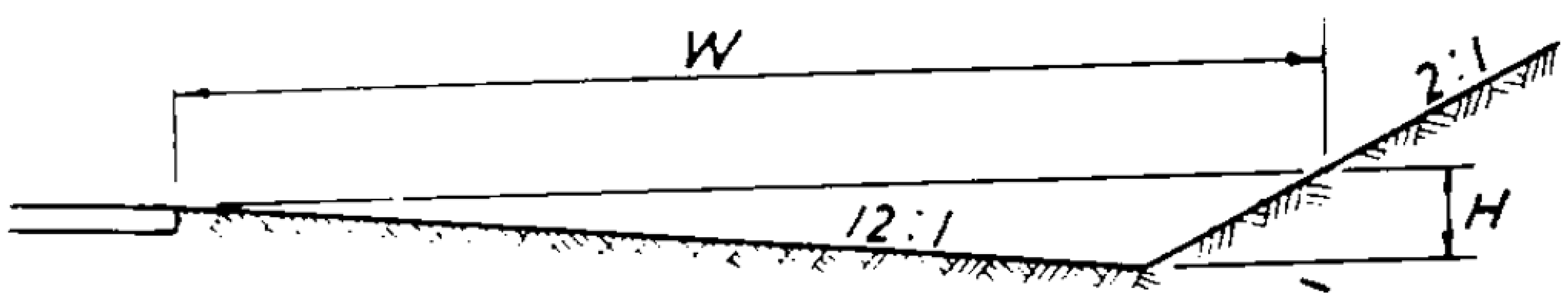
DRAINAGE - DITCHES - COMMON SECTIONS



D-1 SEGMENTAL

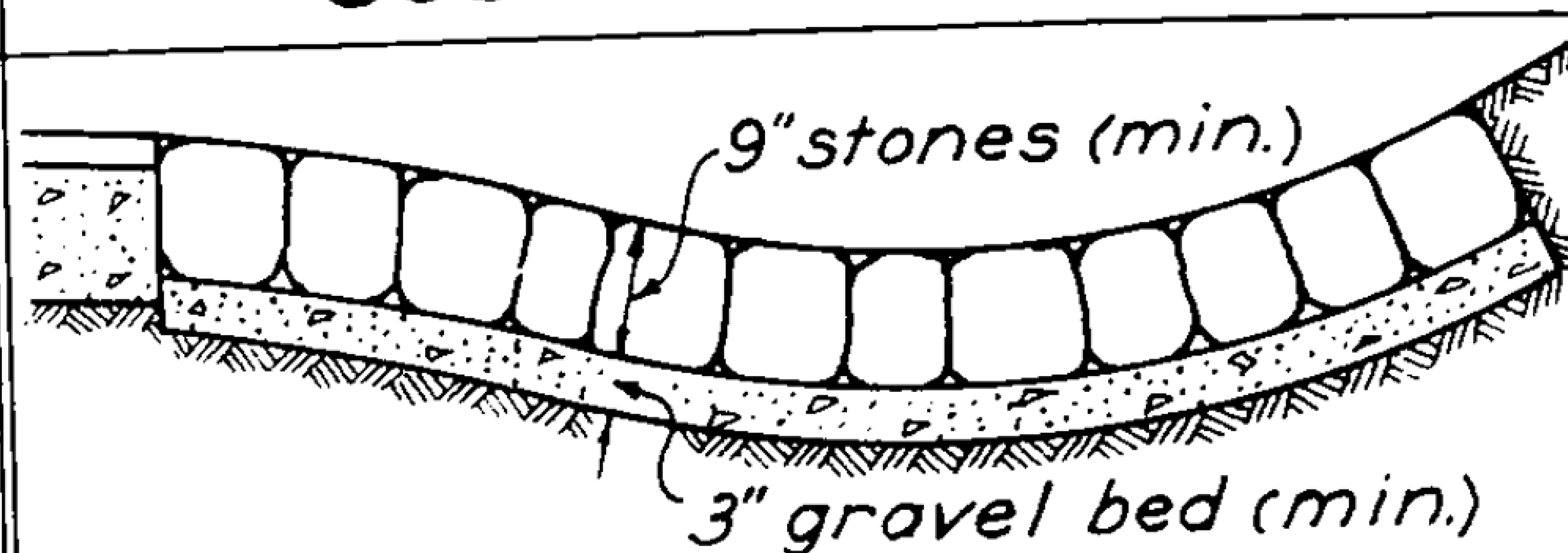


SODDED GUTTER

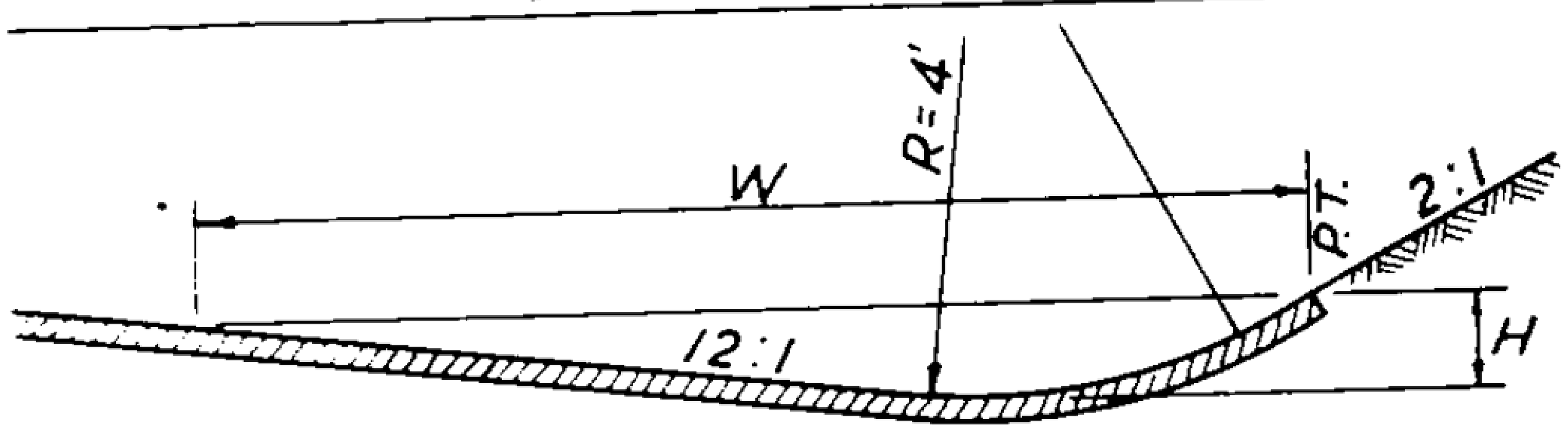


D-1A TRIANGULAR

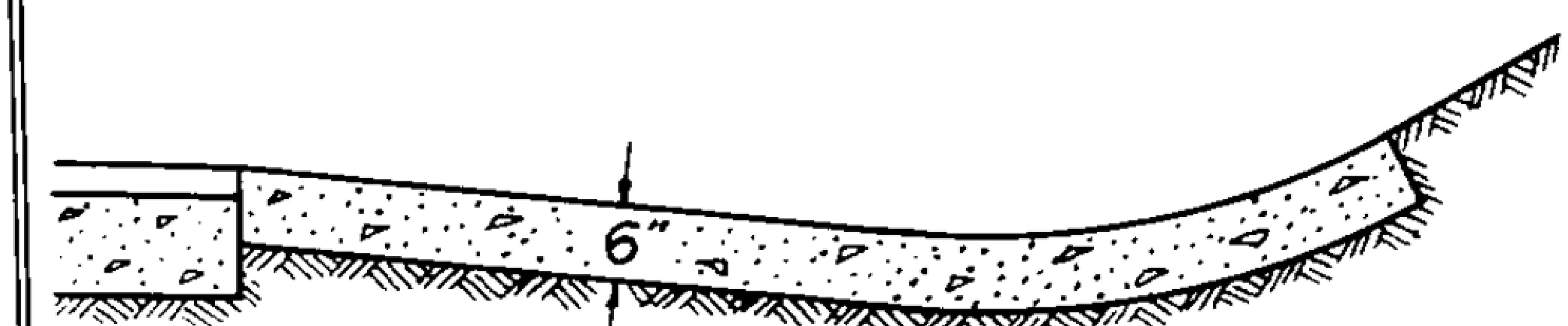
Unequal side slopes



COBBLED GUTTER

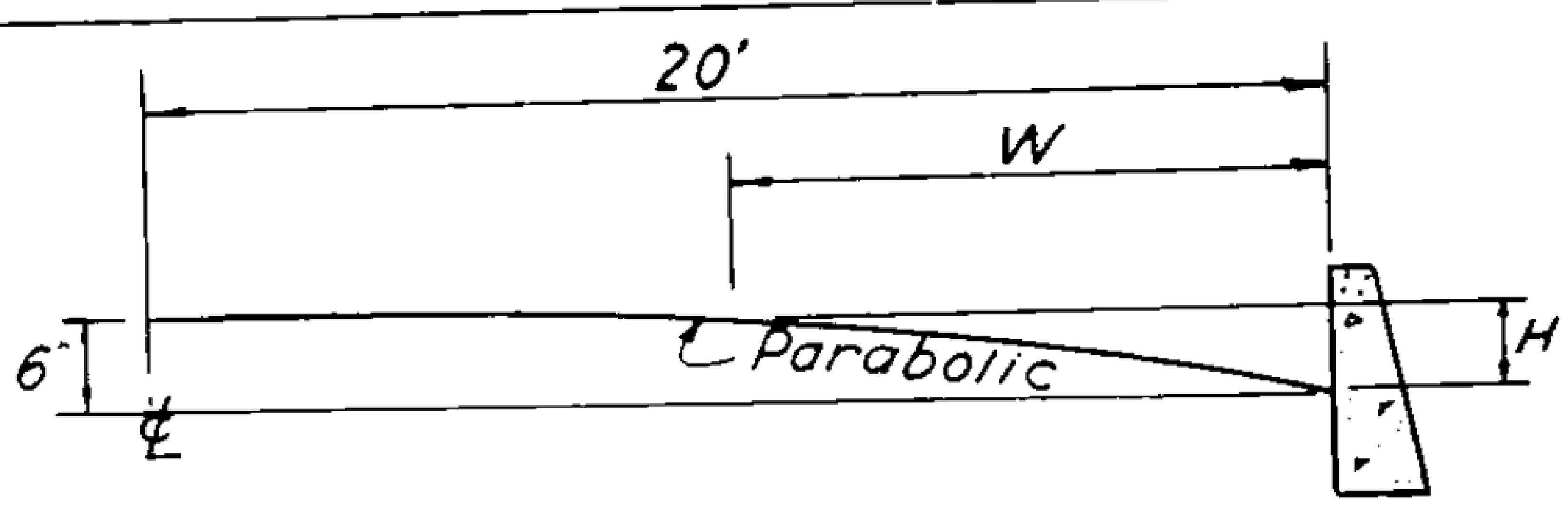


D-1B BITUMINOUS GUTTER

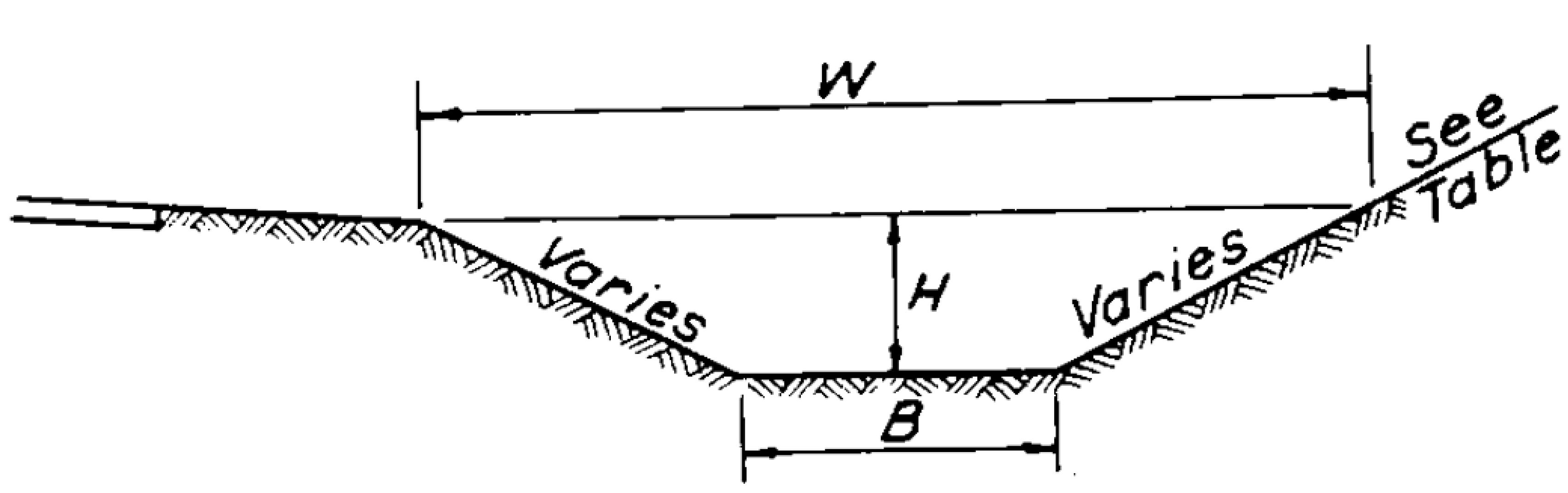


Base required same as for concrete pavement.

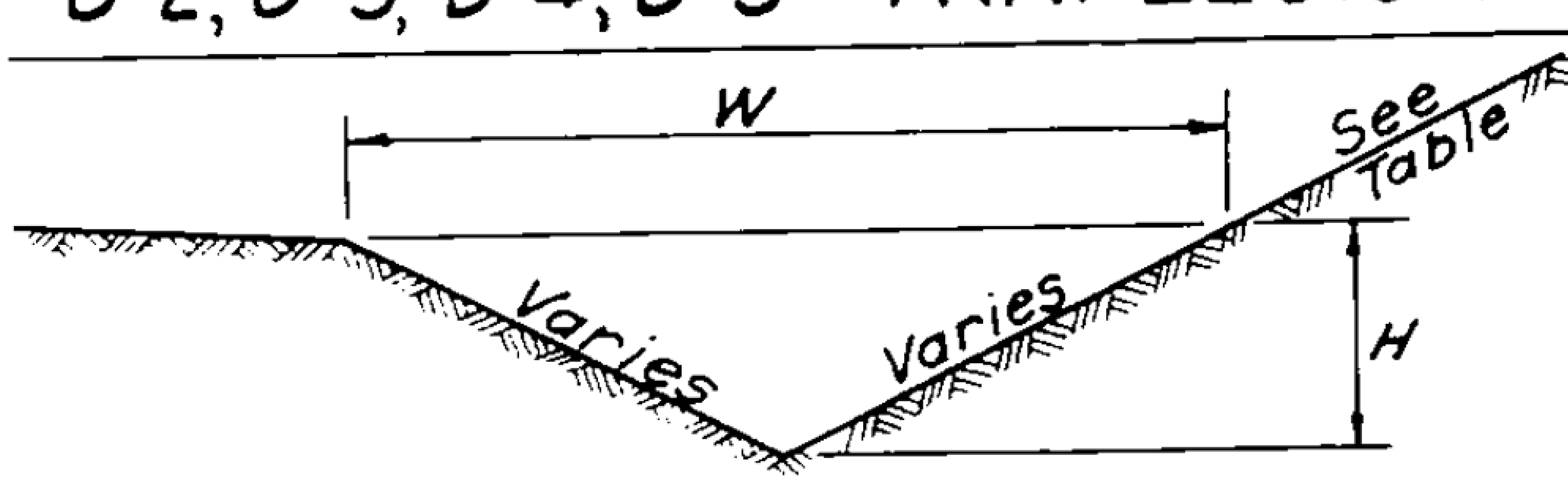
CONCRETE GUTTER



D-1C CURBED CROWNED STREET



D-2, D-3, D-4, D-5 TRAPEZOIDAL



D-6, D-7, D-8, D-9, D-10, D-11

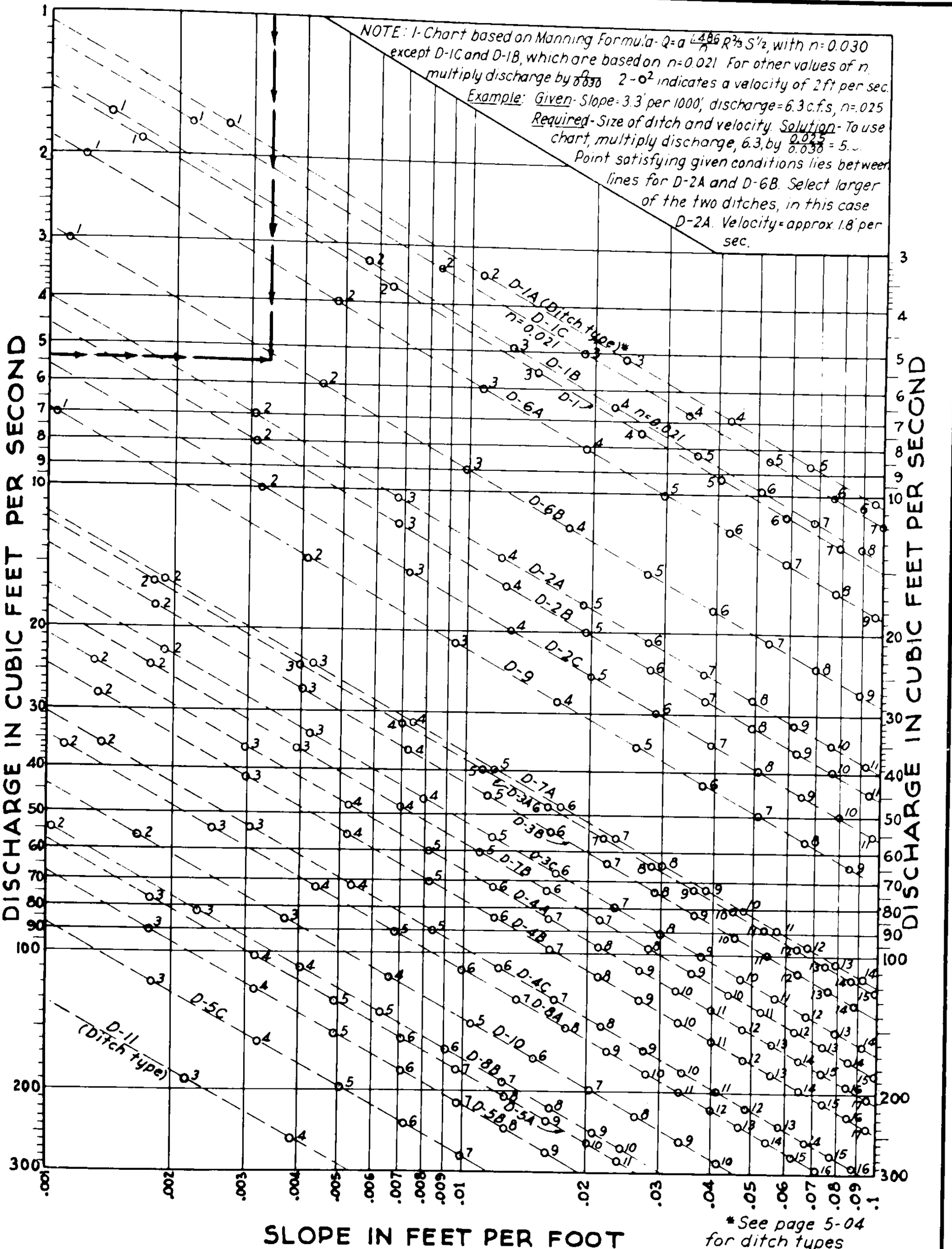
ISOSCELES TRIANGULAR

D-9, D-10 and D-11 - Airport ditches

TABLE A - PROPERTIES OF DITCHES.

NO.	DIMENSIONS				HYDRAULICS			
	SIDE SLOPES	B	H	W	a	p	R	$R^{2/3}$
D-1	—	–	6½"	5'-0"	1.84	5.16	0.356	0.502
D-1A	12:1 & 2:1	–	6"	7'-0"	1.75	7.14	0.245	0.392
D-1B	12:1 & 2:1	–	5"±	7'-0"	1.64	7.08	0.232	0.377
D-1C	½" to 1'-0"	–	4.5"	10'-0"	1.68	10.38	0.162	0.297
D-2A	1½:1'	2'-0"	1'-0"	5'-0"	3.50	5.61	0.624	0.730
B	2:1	2'-0"	1'-0"	6'-0"	4.00	6.47	0.618	0.726
C	3:1	2'-0"	1'-0"	8'-0"	5.00	8.32	0.601	0.712
D-3A	1½:1	3'-0"	1'-6"	7'-6"	7.88	8.41	0.937	0.958
B	2:1	3'-0"	1'-6"	9'-0"	9.00	9.71	0.927	0.951
C	3:1	3'-0"	1'-6"	12'-0"	11.25	12.49	0.901	0.933
D-4A	1½:1	3'-0"	2'-0"	9'-0"	12.00	10.21	1.175	1.114
B	2:1	3'-0"	2'-0"	11'-0"	14.00	11.94	1.173	1.112
C	3:1	3'-0"	2'-0"	15'-0"	18.00	15.65	1.150	1.097
D-5A	1½:1	4'-0"	3'-0"	13'-0"	25.50	14.82	1.721	1.436
B	2:1	4'-0"	3'-0"	16'-0"	30.00	17.42	1.722	1.437
C	3:1	4'-0"	3'-0	22'-0"	39.00	22.97	1.698	1.423
D-6A	2:1	–	1'-0"	4'-0"	2.00	4.47	0.447	0.584
B	3:1	–	1'-0"	6'-0"	3.00	6.32	0.475	0.609
D-7A	2:1	–	2'-0"	8'-0"	8.00	8.94	0.895	0.929
B	3:1	–	2'-0"	12'-0"	12.00	12.65	0.949	0.965
D-8A	2:1	–	3'-0"	12'-0"	18.00	13.42	1.341	1.216
B	3:1	–	3'-0"	18'-0"	27.00	18.97	1.423	1.265
D-9	7:1	–	1'-0"	14'-0"	7.00	14.14	0.495	0.626
D-10	7:1	–	2'-0"	28'-0"	28.00	28.28	0.990	0.993
D-11	7:1	–	3'-0"	42'-0"	63.00	42.43	1.485	1.302

DRAINAGE-DITCHES-COMMON SECTIONS



DRAINAGE - SUBDRAINAGE § -1

TABLE A - SUBDRAIN DEPTH AND SPACING * FOR CONTROLLING GROUND WATER LEVEL.

SOIL CLASSES	PERCENTAGE OF EACH CLASS OF SOIL			DEPTH OF BOTTOM OF DRAIN IN FEET	DISTANCE BETWEEN SUBDRAINS IN FEET
	SAND	SILT	CLAY		
Sand	80-100	0-20	0-20	3-4 2-3	150-300 100-150
Sandy Loam	50-80	0-50	0-20	3-4 2-3	100-150 85-100
Loam	30-50	30-50	0-20	3-4 2-3	85-100 75-85
Silt Loam	0-50	50-100	0-20	3-4 2-3	75-85 65-75
Sandy Clay Loam	50-80	0-30	20-30	3-4 2-3	65-75 55-65
Clay Loam	20-50	20-50	20-30	3-4 2-3	55-65 45-55
Silty Clay Loam	0-30	50-80	20-30	3-4 2-3	45-55 40-45
Sandy Clay	50-70	0-20	30-50	3-4 2-3	40-45 35-40
Silty Clay	0-20	50-70	30-50	3-4 2-3	35-40 30-35
Clay	0-50	0-50	30-100	3-4 2-3	30-35 25-30

* From Airport Drainage, by Armco International Corp. Above data to be considered rough approximations only.

TABLE B - SUBSURFACE RUNOFF. **

MEAN ANNUAL † PRECIPITATION (INCHES)	SUBSURFACE RUNOFF	
	INCHES PER DAY PER SQ. FOOT	C.F.S. PER ACRE
30 OR LESS	0.25	0.0105
30-40	0.35	0.0147
40-50	0.50	0.0210
50 OR MORE	0.75	0.0315

** Based on Eng. Manual, U.S. Corps of Engrs.
† See Fig. A, Page 6-02.

EXAMPLE:- Given:- Area in central Ohio, Fig. C(e) below, Sandy loam, 800 ft. x 1200 ft., to be subdrained by system of parallel laterals discharging into one submain. Required: Depth and spacing of laterals and discharge from submain = Q. Read in Tab. A, at left for "Sandy loam" minimum depth = 3 feet, spacing = 100 ft. In Fig. A, Pg. 6-02 find mean annual precipitation = 37.5; enter Tab. B, above with 37.5 inches mean annual precipitation; read subsurface runoff = 0.0147 c.f.s.

Therefore $Q = \dfrac{800 \times 1875 \times 0.0147}{43{,}560} = 0.5$ C.f.s.

For size of Drains see Page 5-24.

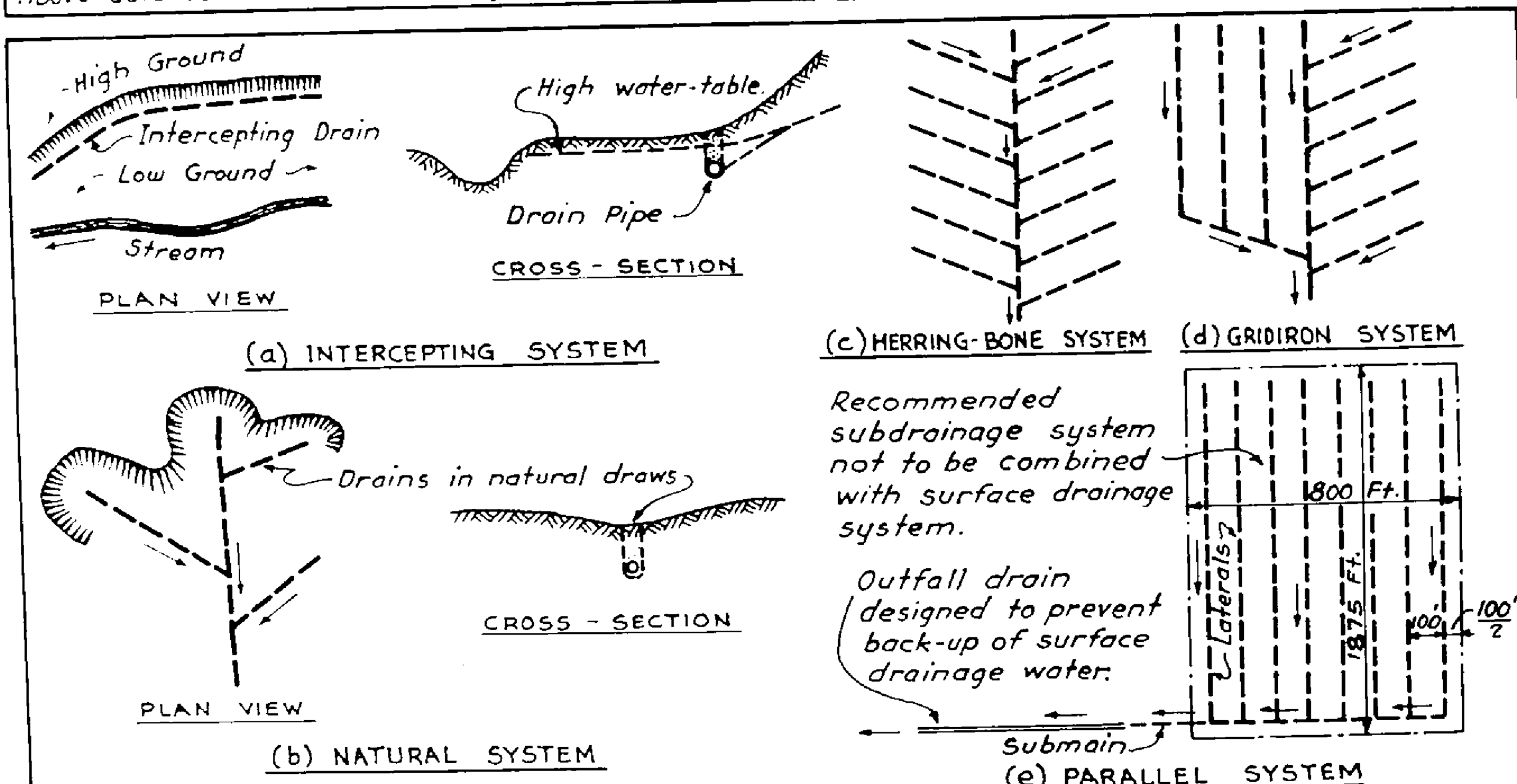


FIG. C - TYPES OF SUBDRAINAGE SYSTEMS. ††

†† From Handbook of Culvert and Drainage Practice, by Armco Drainage Products Assoc.
§ For additional data on Subdrainage, see "Soil Mechanics" section.

DRAINAGE - SUBDRAINAGE*-2

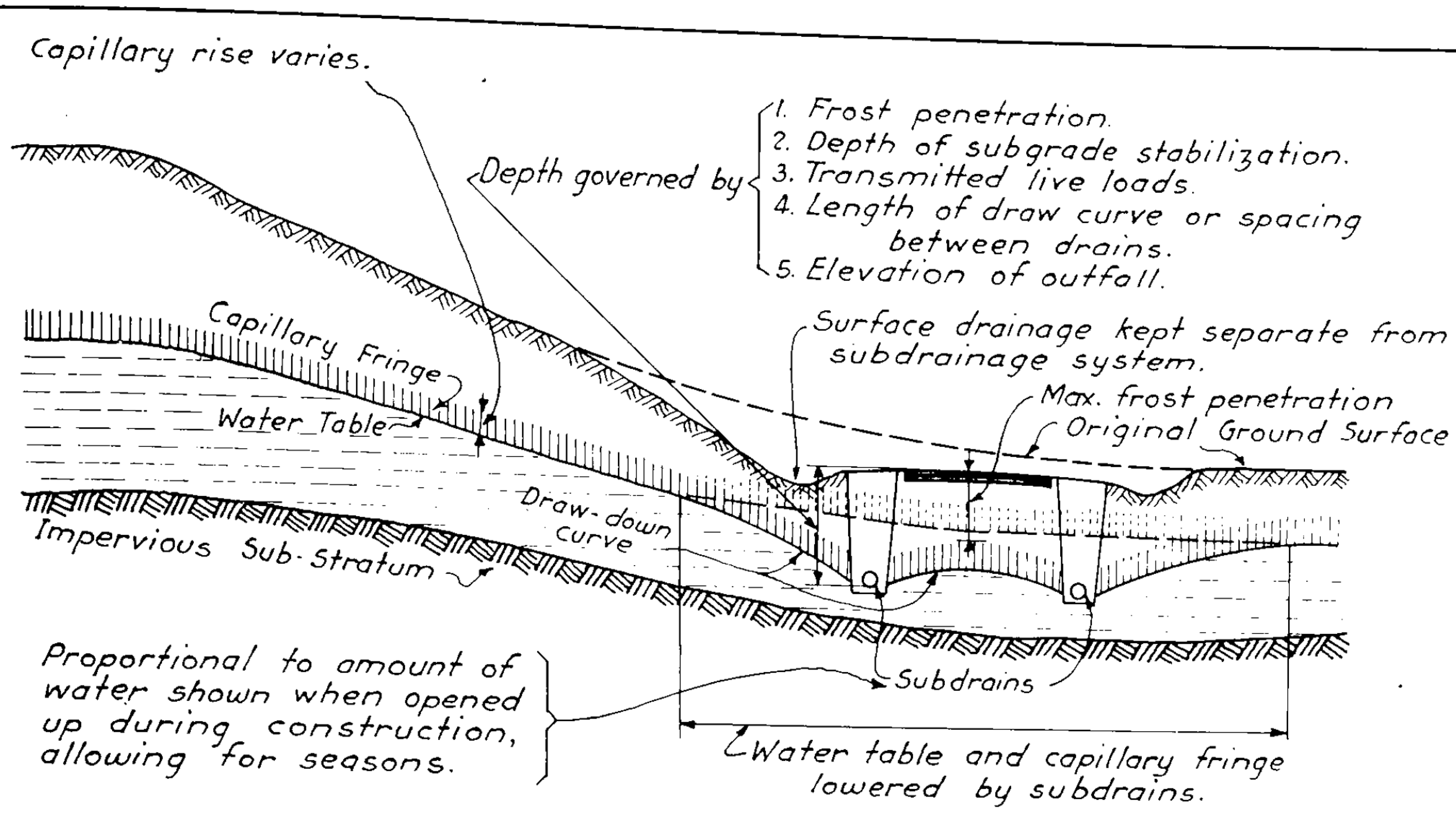


FIG. A - CROSS-SECTION OF HIGHWAY SUBDRAINAGE.

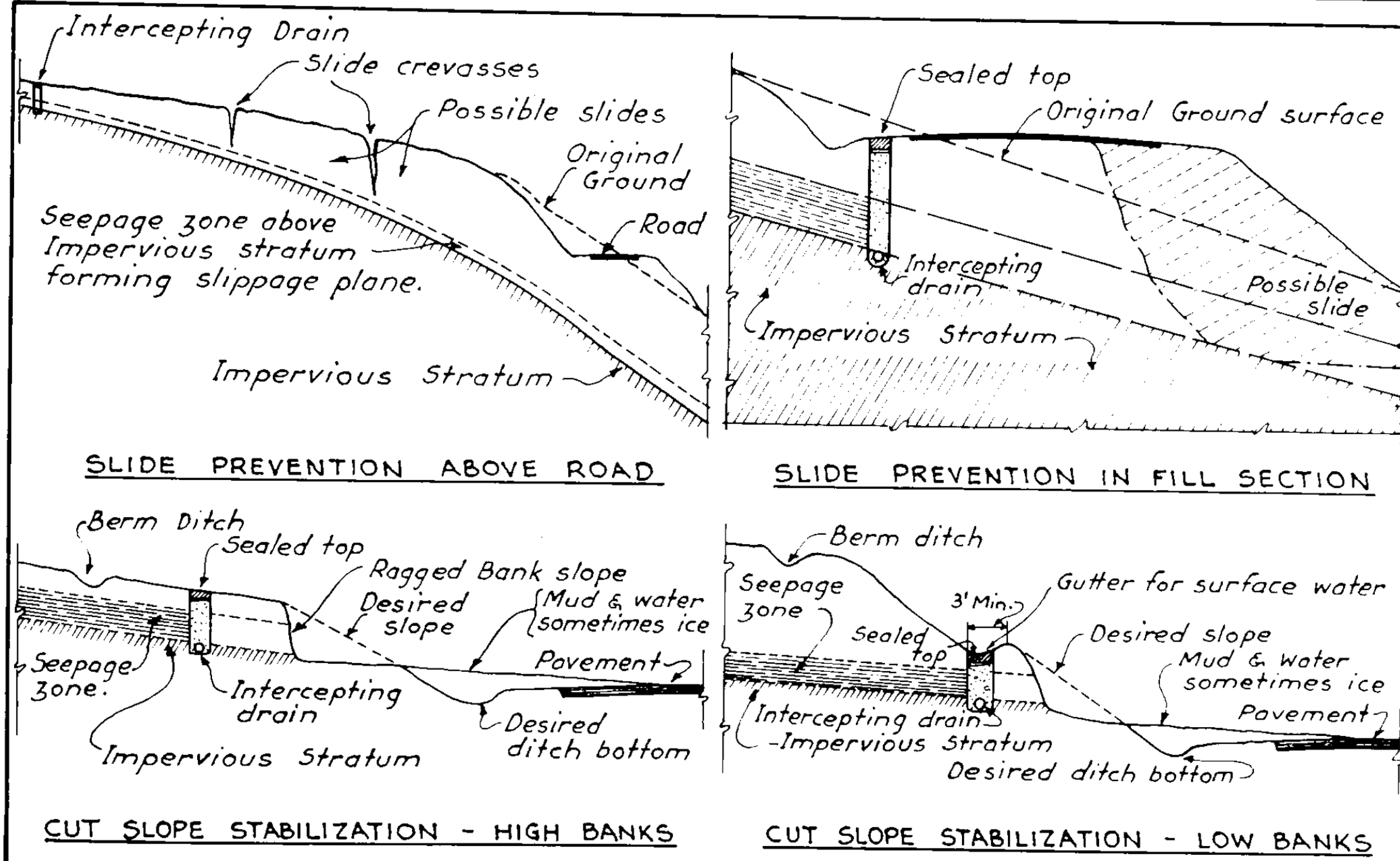


FIG. B - INTERCEPTING SUBDRAINS.†

† Adapted from Handbook of Culvert & Drainage Practice, Armco Drainage Products Assoc

* For additional data on Subdrainage, see section on "Soils" pg. 3-01 to pg. 3-25

DRAINAGE - HEADWALLS

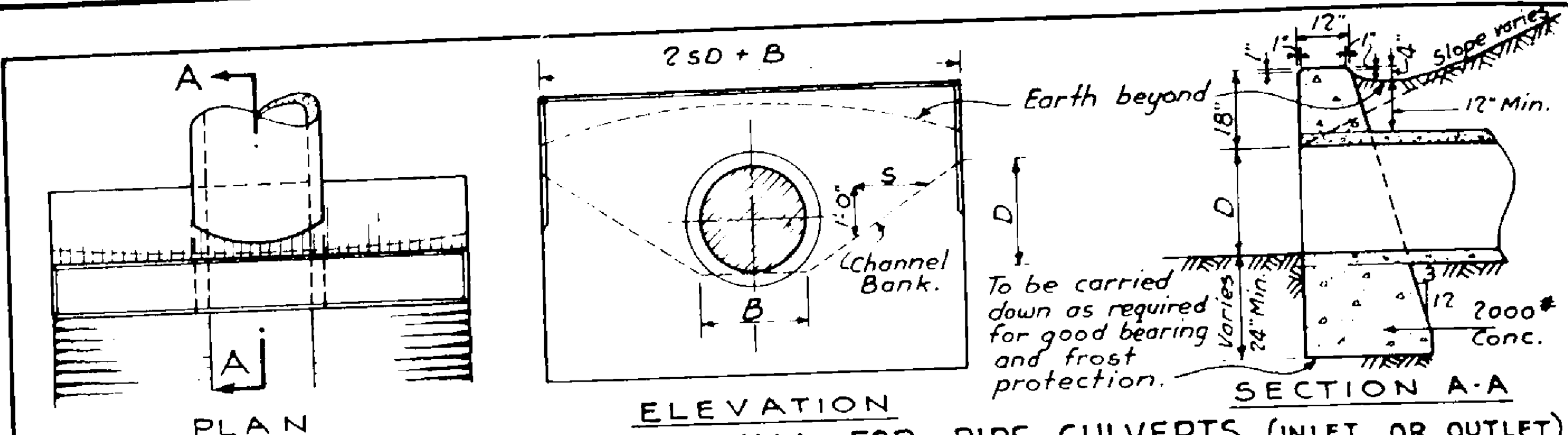


FIG. A - STRAIGHT CONCRETE HEADWALL FOR PIPE CULVERTS (INLET OR OUTLET).

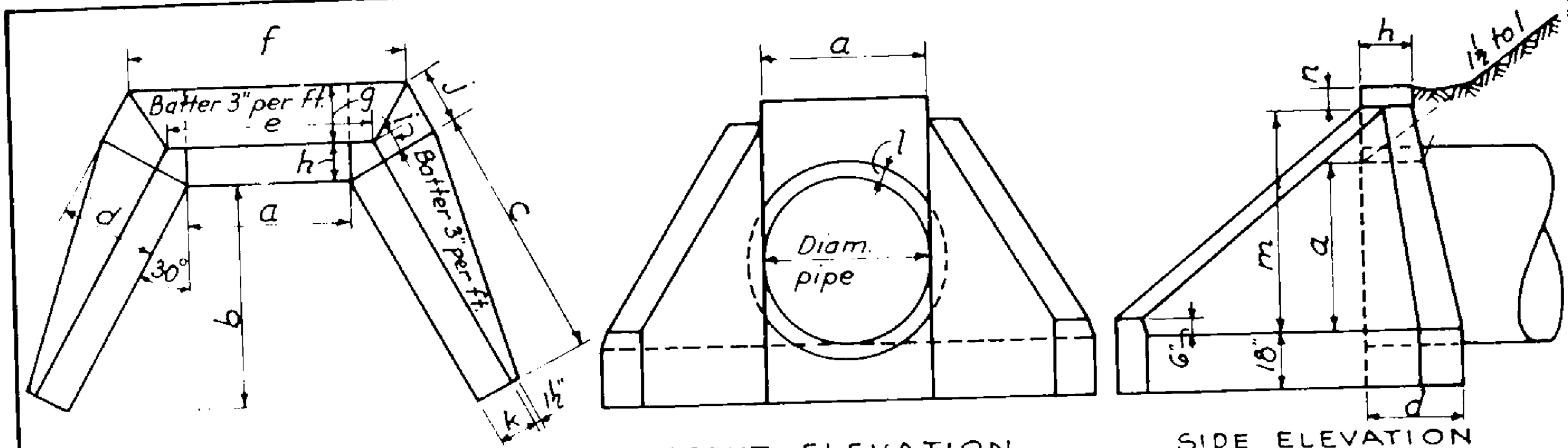
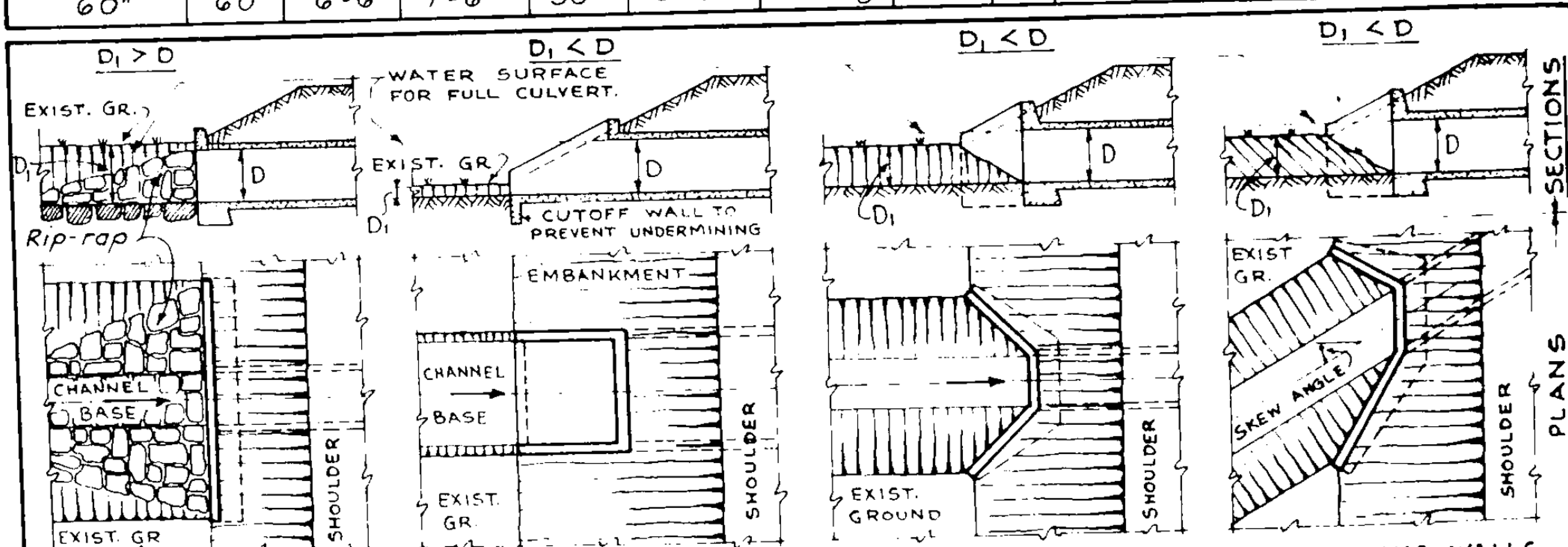


FIG. B - CONCRETE HEADWALL WITH WING WALLS FOR PIPE CULVERTS.*

TABLE C - DIMENSIONS FOR HEADWALLS WITH WINGWALLS IN FIG. B *

DIAMETER OF PIPE	a	b	c	d	e	f	g	h	i	j	k	l	m	n
42"	42"	5'-0"	5'-9¼"	23½"	4'-5½"	5'-9"	13½"	10"	5¾"	13½"	10"	4½"	4'-6"	3½"
48"	48"	5'-6"	6'-4¼"	25"	4'-11½"	6'-5"	15"	10"	5¾"	14½"	10"	5"	5'-0"	4"
54"	54"	6'-0"	6'-11⅛"	27½"	5'-6¾"	7'-1¾"	16½"	11"	6⅜"	15⅞"	11"	5½"	5'-6"	4½"
60"	60"	6'-6"	7'-6"	30"	6'-2"	7'-10⅝"	18"	12"	7"	17⅜"	12"	6"	6'-0"	5"



STRAIGHT HEADWALL PARALLEL TO ROAD
FOR CASE WHERE TOP OF DITCH SIDE IS ABOVE TOP OF CULVERT OR PIPE.

WING WALLS NORMAL TO ROAD
SHALLOW DITCHES OR UNDERPASS

FLARED WING WALLS SYMMETRICAL
FOR CASES WHERE TOP OF PIPE IS ABOVE TOP OF DITCH SIDES.

FLARED WING WALLS SKEWED CULVERT

FIG. D - HEADWALL DESIGN AS CONTROLLED BY TOPOGRAPHY.

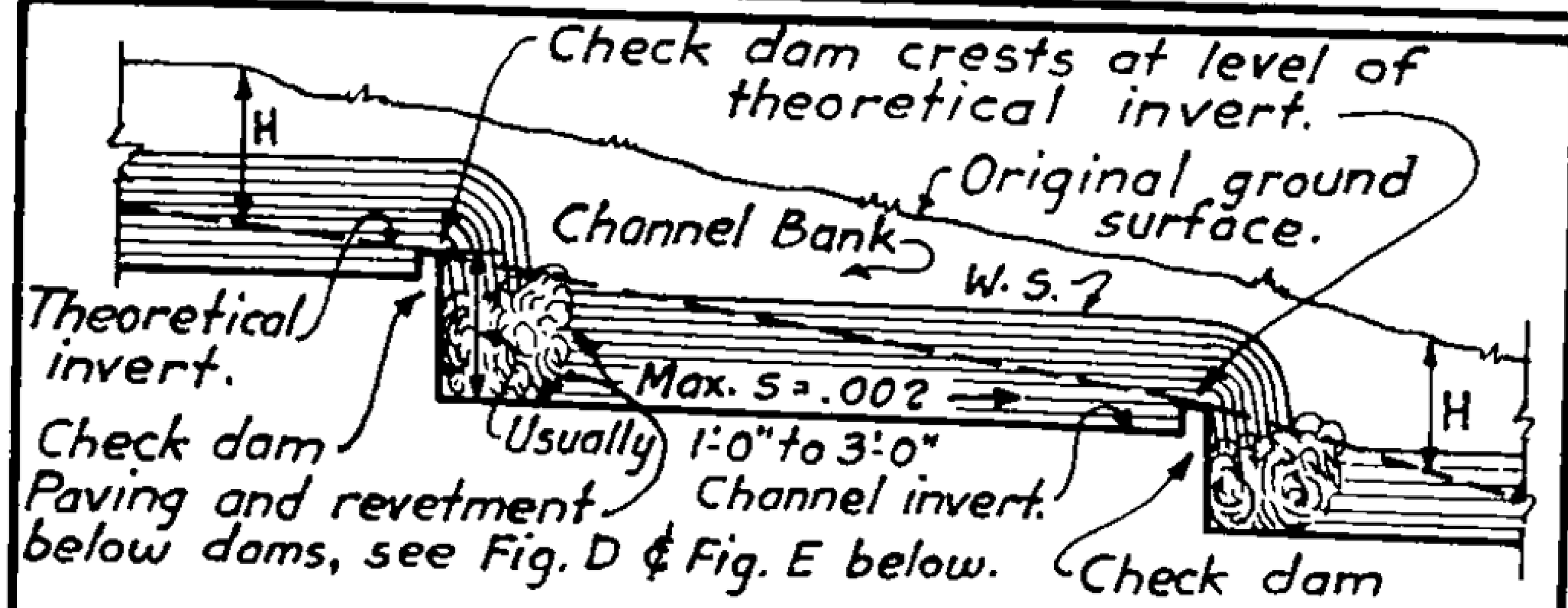
* Virginia Dept. of Highways, after Urquhart, Civil Engineering Handbook, McGraw-Hill

DRAINAGE - EROSION PROTECTION

TABLE A - MEAN VELOCITIES WHICH WILL NOT ERODE CHANNELS AFTER AGING.		
MATERIAL OF CHANNEL BED	VELOCITY IN FEET PER SEC.	
	SHALLOW DITCH	DEEP CANAL *
Fine sand or silt, non-colloidal	0.50-1.50	1.50-2.50
Coarse sand or sandy loam, non-colloidal	1.00-1.50	1.75-2.50
Silty or sand loam " "	1.00-1.75	2.00-3.00
Clayey loam or sandy clay " "	1.50-2.00	2.25-3.50
Fine gravel	2.00-2.50	2.50-5.00
Colloidal clay or non-colloidal gravelly loam	2.00-3.00	3.00-5.00
Colloidal, well graded gravel	2.25-3.50	4.00-6.00
Pebbles, broken stone, shales or hardpan	2.50-4.00	5.00-6.50
Sodded gutters (See p. 5-04)	3.00-5.00	—
Cobbled gutters, not grouted, or bituminous paving (See p. 5-04)	5.00-7.50	—
Stone masonry	7.50-15.00	—
Solid rock or concrete	15.00-25.00	—

AGING OF CHANNELS increases resistance to erosion as density and stability of channel bed improve due to deposit of silt in interstices and as cohesion increases due to cementation of soil by colloids. New channels may be safely operated at less than maximum design velocities by use of temporary check structures.

VELOCITIES are to be reduced for depths of flow under 6 inches and for water which may transport abrasive materials.



LONGITUDINAL SECTION THROUGH CHANNEL

FIG. B - CHECK DAM LOCATION.

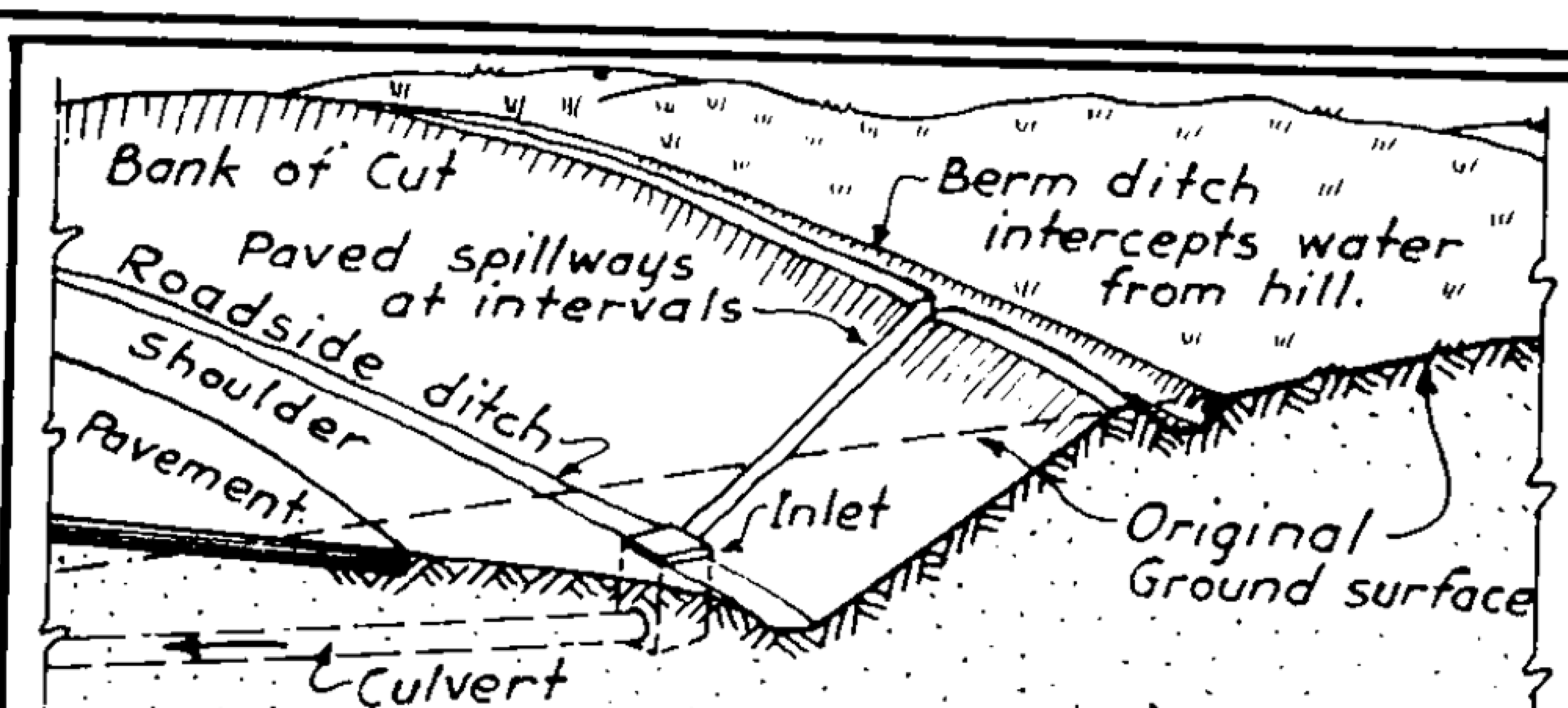


FIG. C - EROSION PROTECTION FOR EARTH BANK.

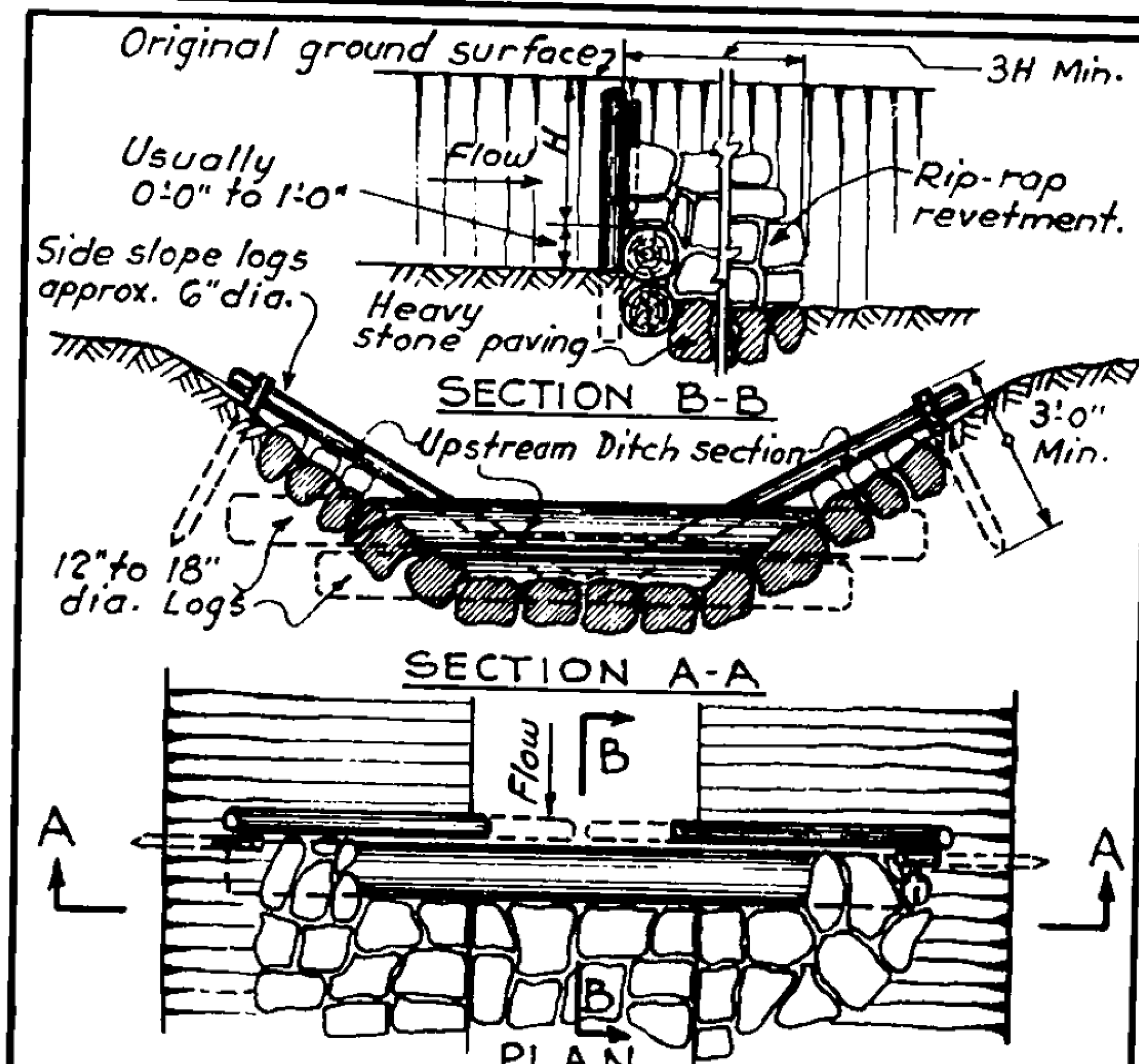


FIG. D - LOG CHECK DAM.

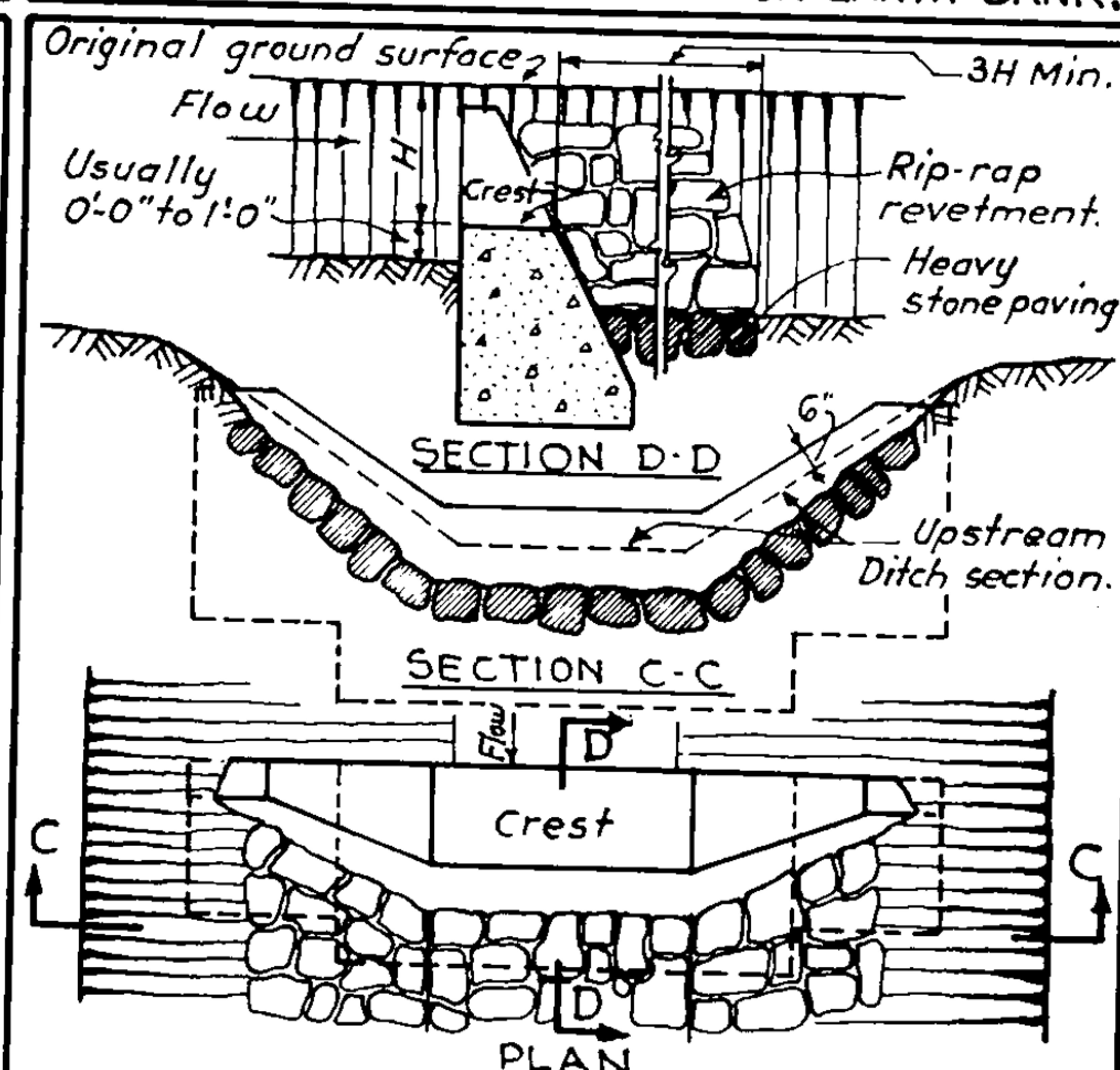
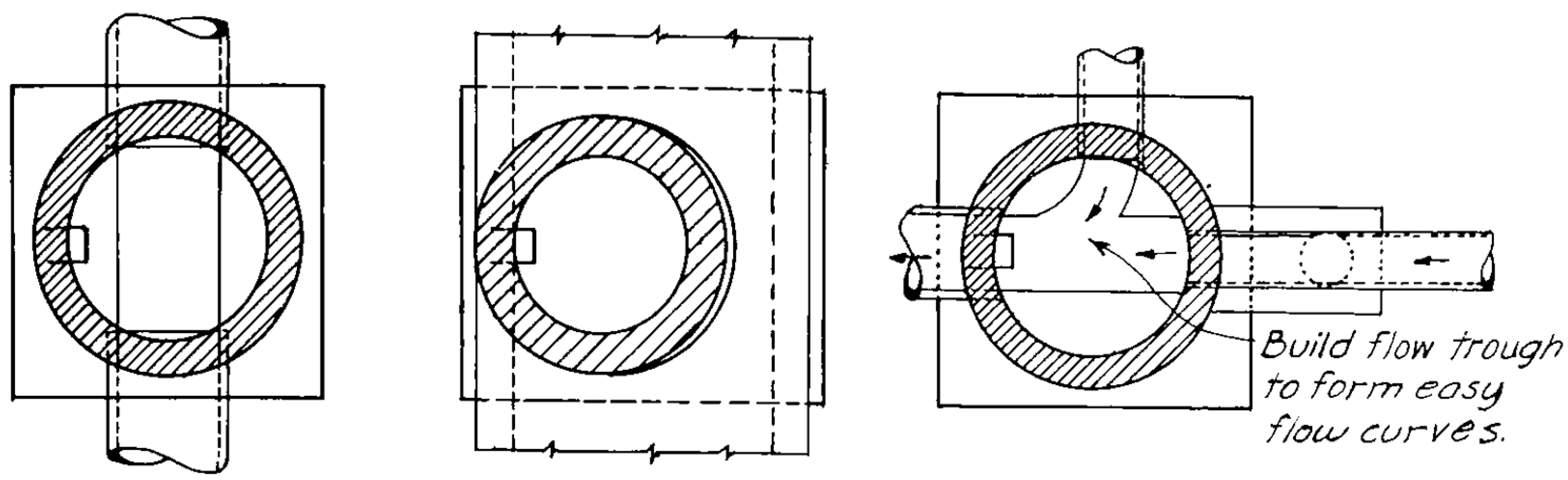


FIG. E - CONCRETE CHECK DAM.

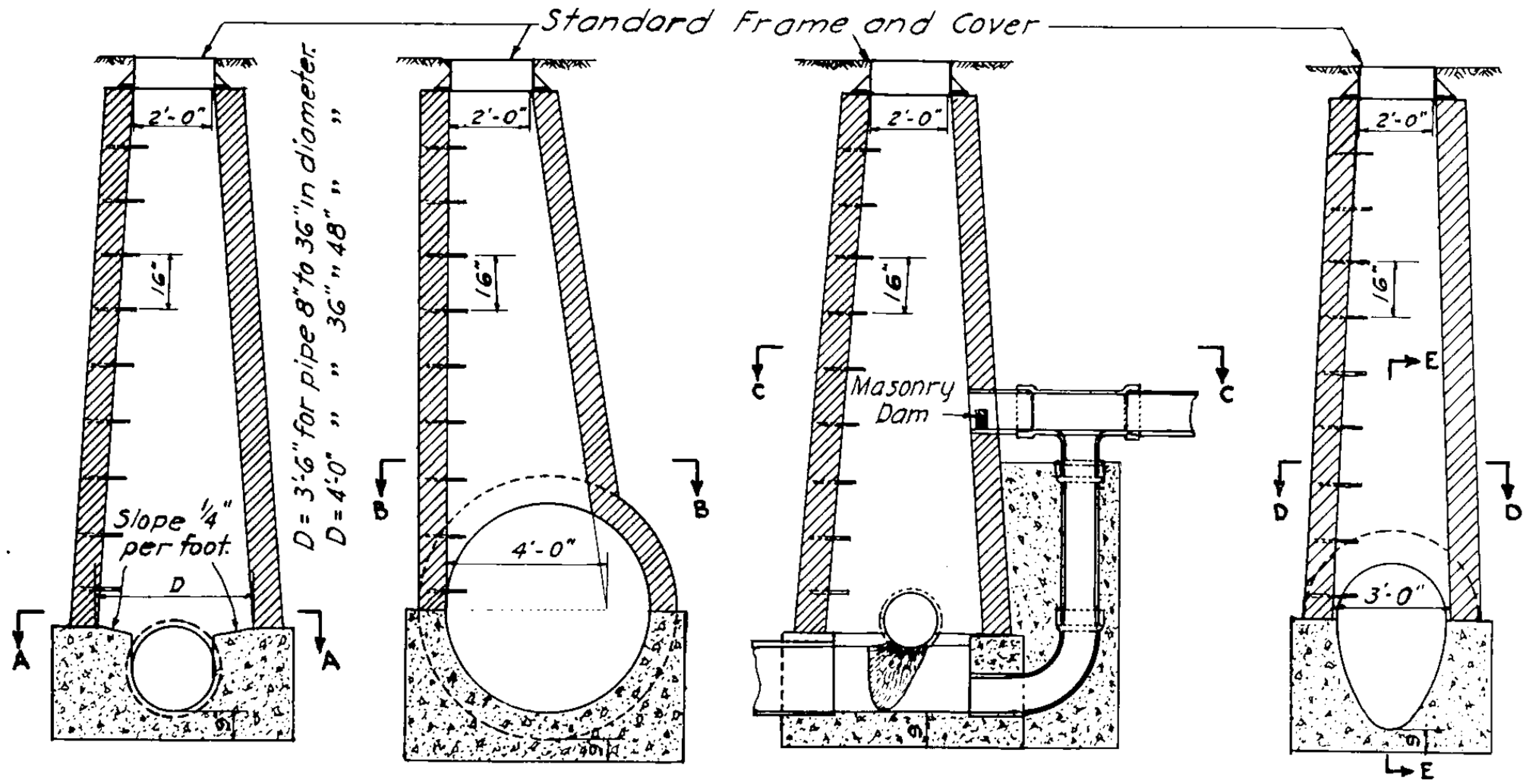
* *Based on Report of Special Committee on Irrigation Research, Am. Soc. Civil Engrs. 1926.*

DRAINAGE & SEWERAGE - MANHOLES



SECTION A-A SECTION B-B SECTION C-C SECTION D-D

NOTE:- Walls to be 8 inches thick to 13 foot depth, walls to be increased to 12 inch thickness in section below 13 foot depth.

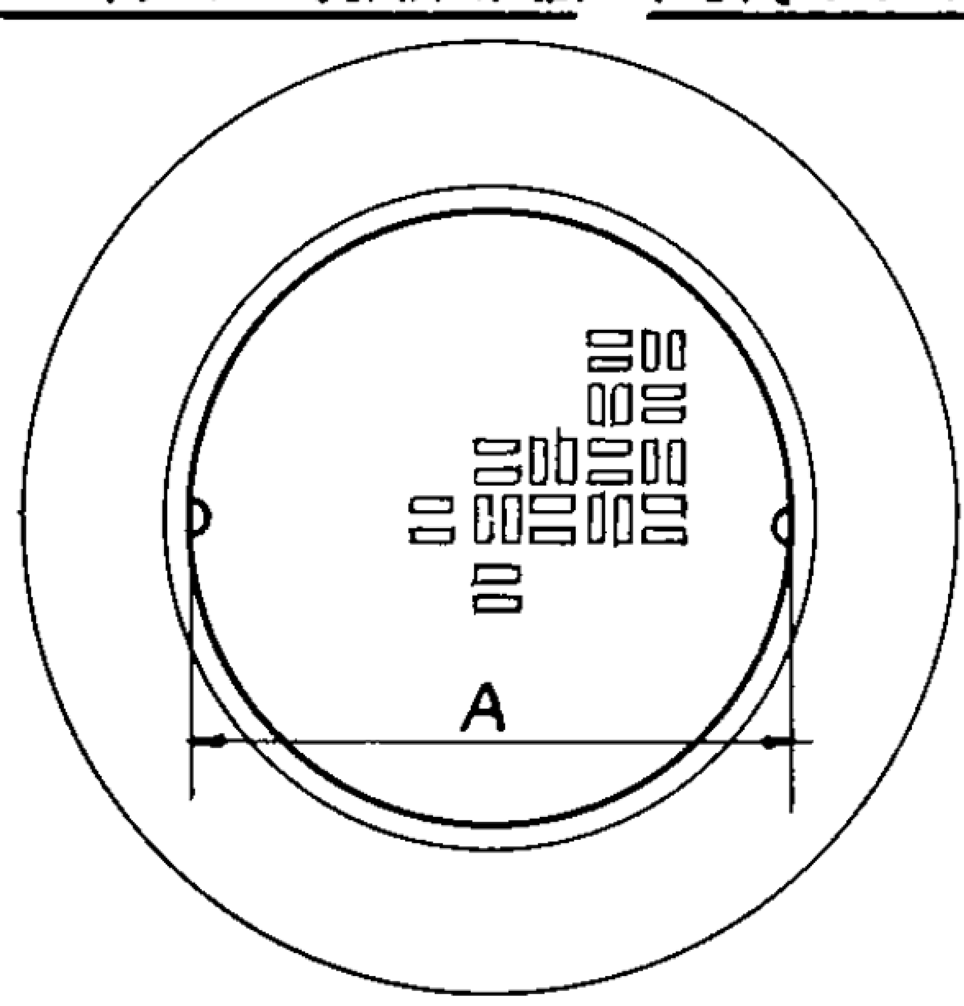


SECTION THROUGH TYPICAL MANHOLE. FOR 8" TO 48" DIA. PIPE.

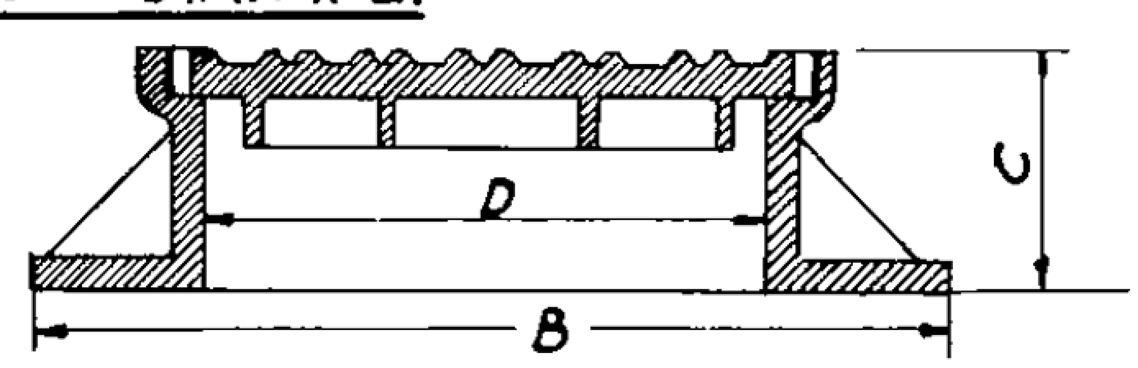
SECTION THROUGH MANHOLE FOR 54" & 60" DIA. PIPE.

SECTION THROUGH TYPICAL DROP MANHOLE.

SECTION THROUGH 4'-0" x 3'-0" MANHOLE ON 3'-6" x 2'-4" & 4'-0" x 2'-8" EGG SHAPED SEWER.



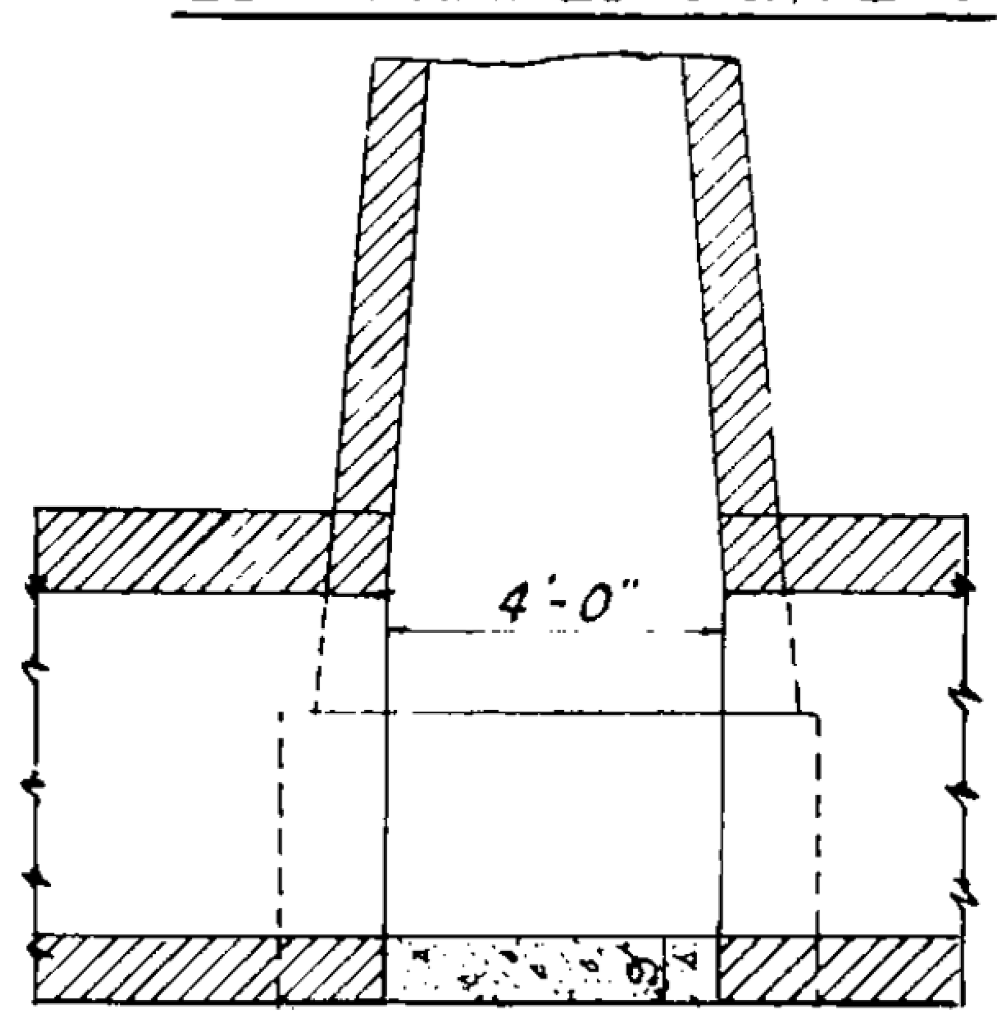
PLAN



SECTION

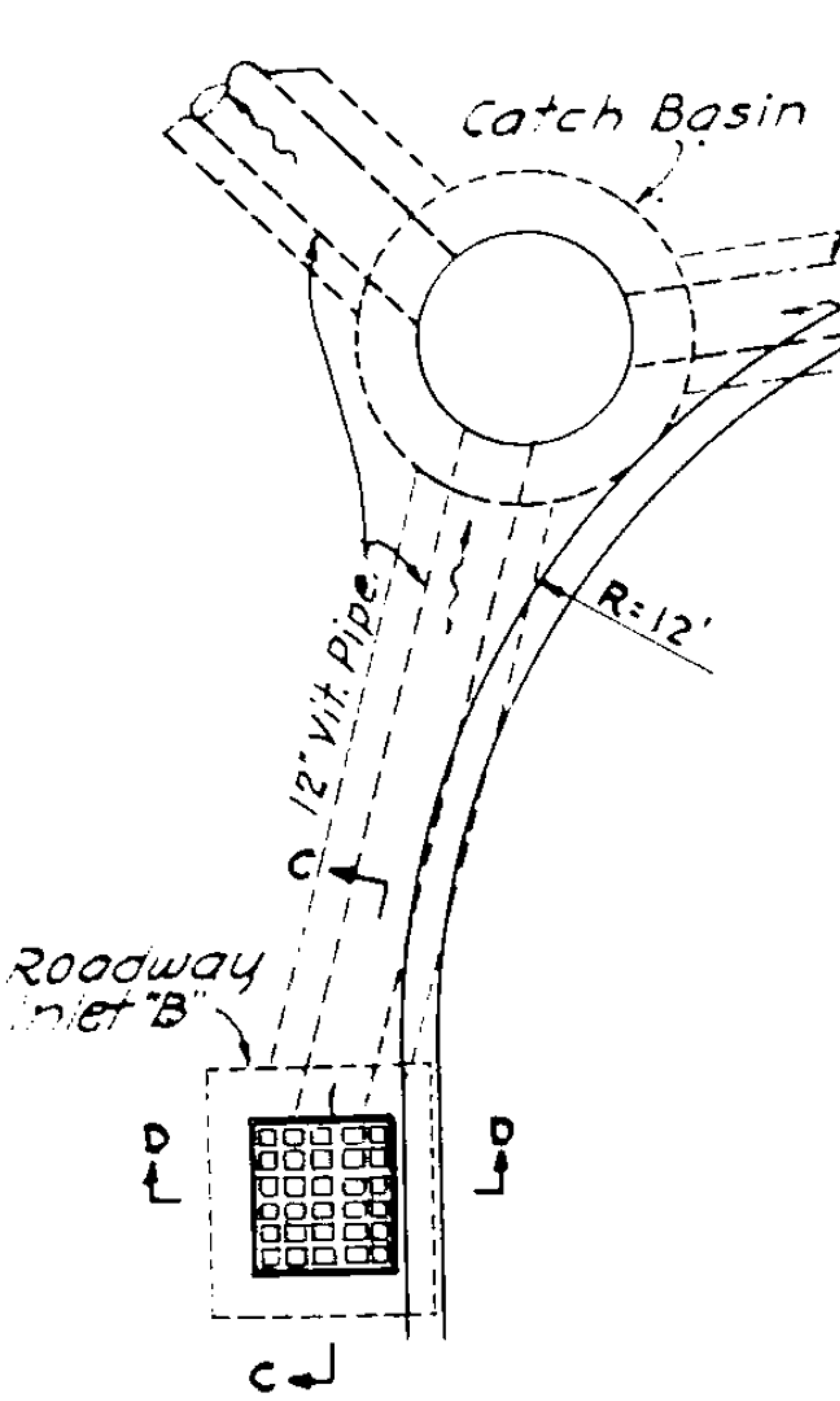
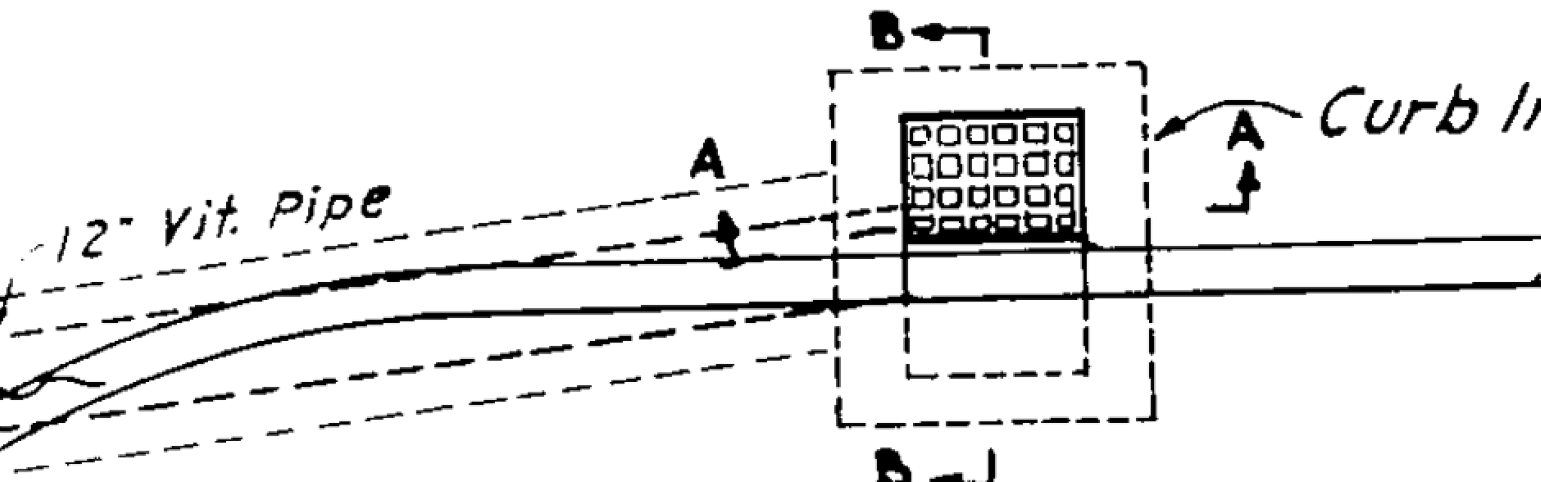
A	B	C	D
22 1/2	32 1/2	8	20
25 3/4	36	8	24
32	42	8	30
38 1/2	48	8	36
44 1/2	54	8	42
49 1/2	60	8	48

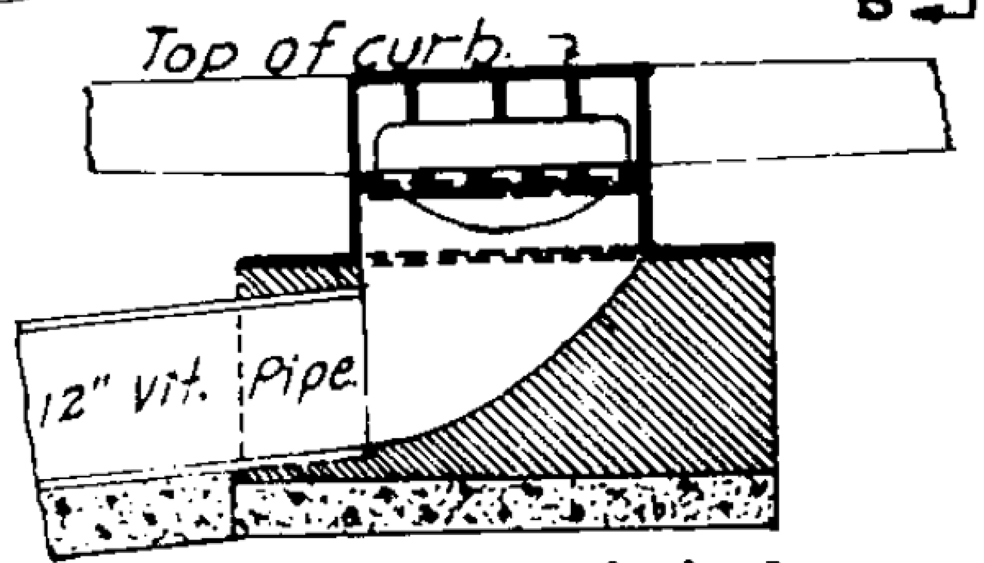
TYPICAL MANHOLE HEAD & COVER.



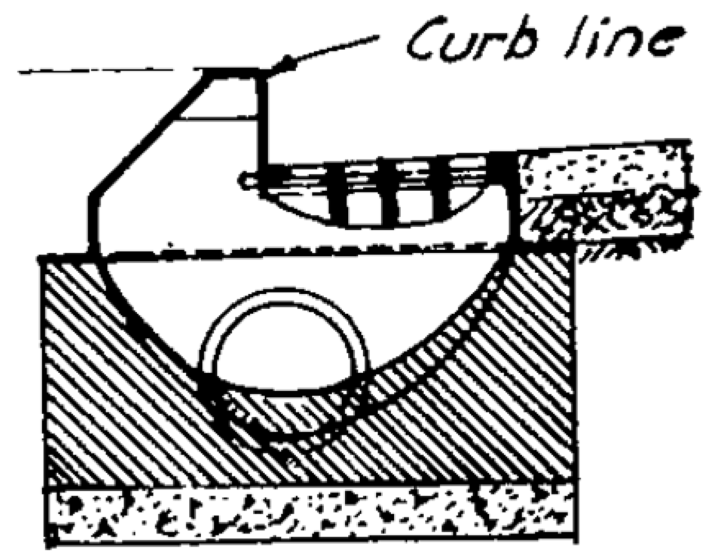
SECTION E-E

DRAINAGE & SEWERAGE - INLETS & CATCH BASINS

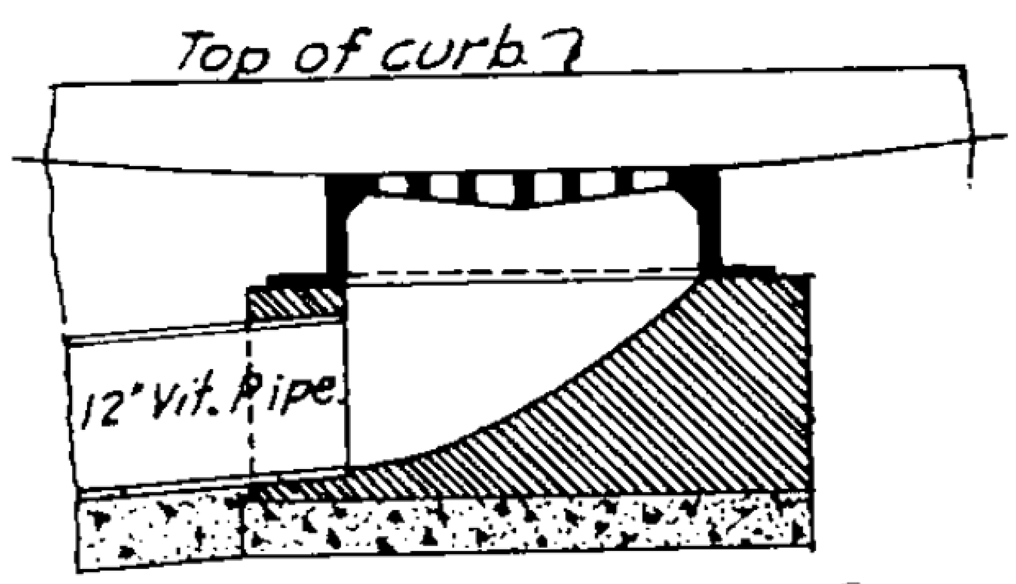


SECTION A-A

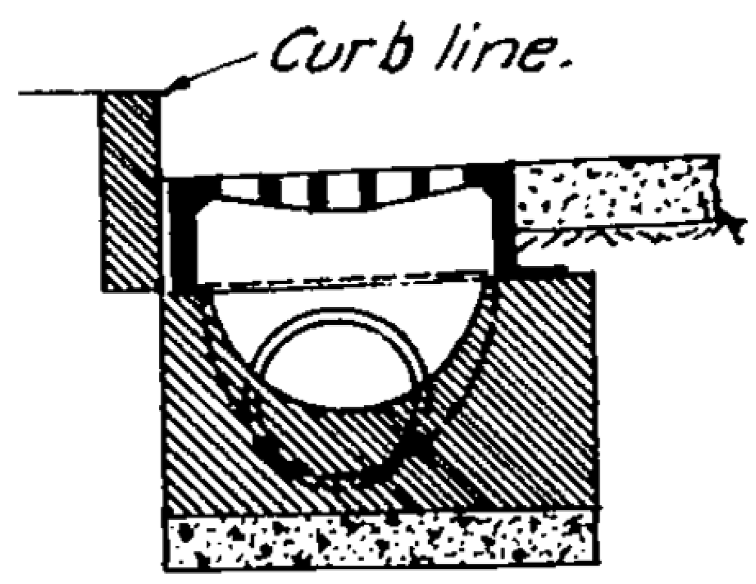


SECTION B-B

DETAILS OF CURB INLET "A"



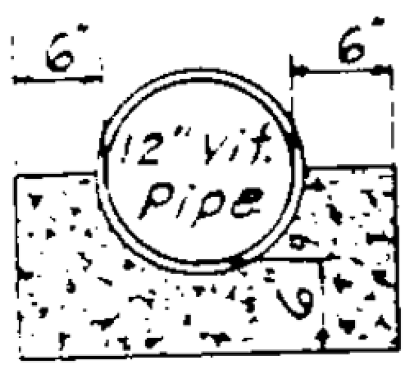
SECTION C-C



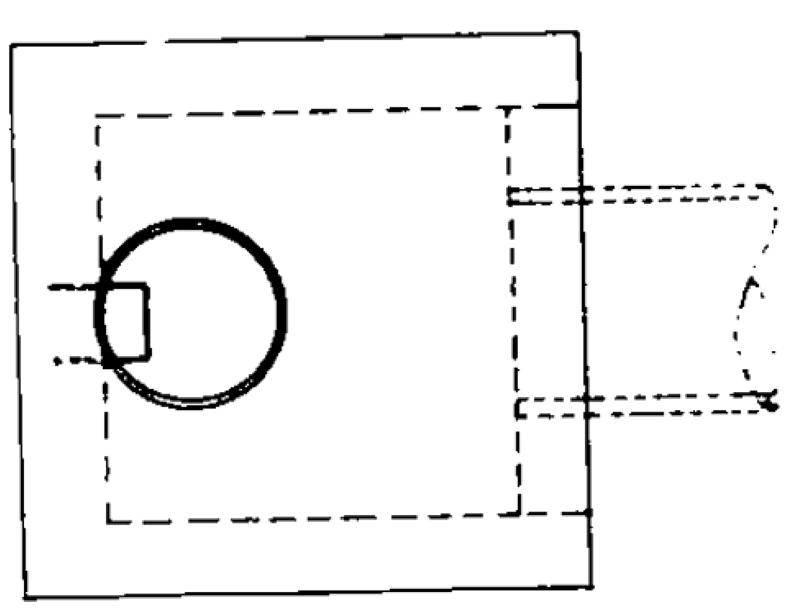
SECTION D-D

DETAILS OF ROADWAY INLET "B"

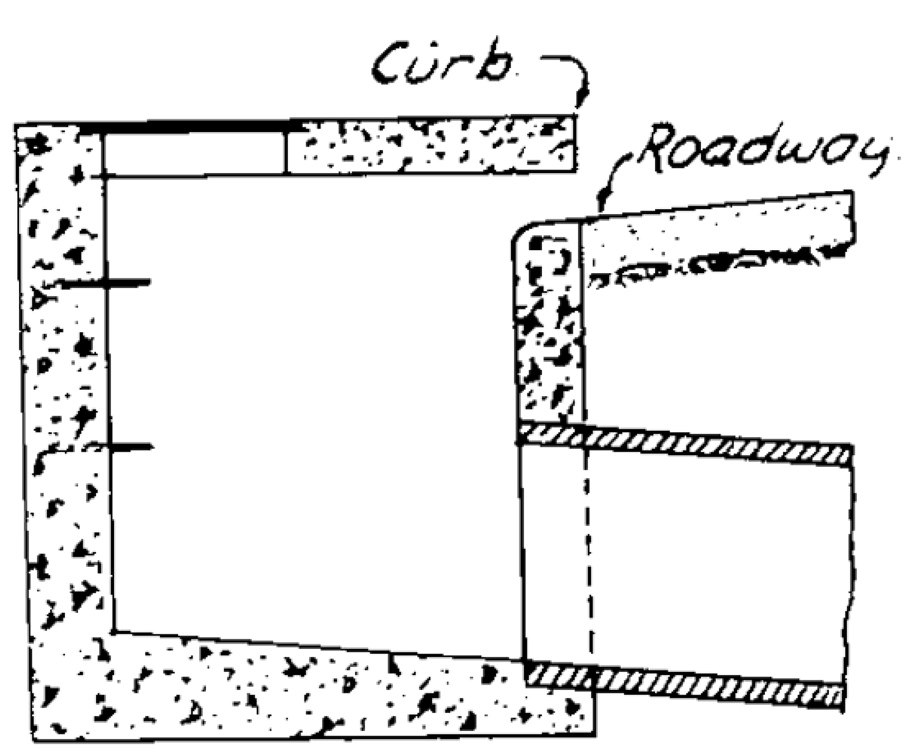
Standard in Borough of Manhattan, N.Y.C.



DETAIL OF CONCRETE CRADLE



PLAN



SECTION E-E
INLET

NOTE;- *Inlet to be constructed of brick or concrete to the dimensions and of the shape shown, and to be smoothly plastered both inside and outside with a layer of cement mortar ½ inch thick.*

The interior of the inlet is to be sloped downwards from all sides towards the outlet.

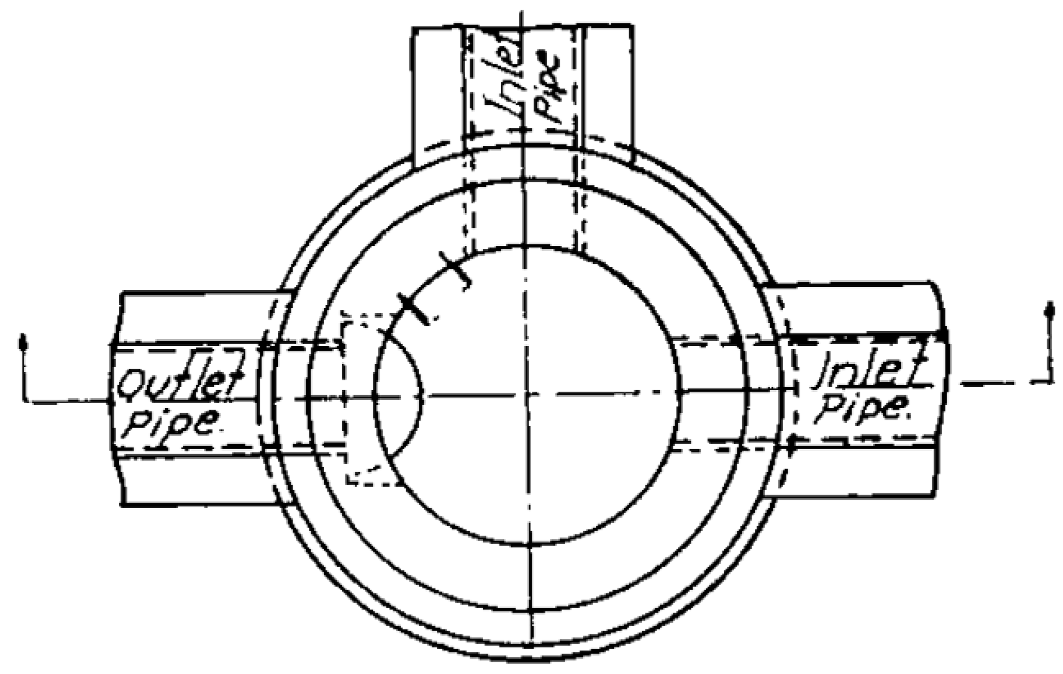
Wherever possible culvert connection shall be laid in a 6 inch concrete cradle, and sufficient concrete placed under inlet to provide a maximum thickness of 6 inches.

Depth of inlet is dependent upon size of pipe and required cover over pipe.

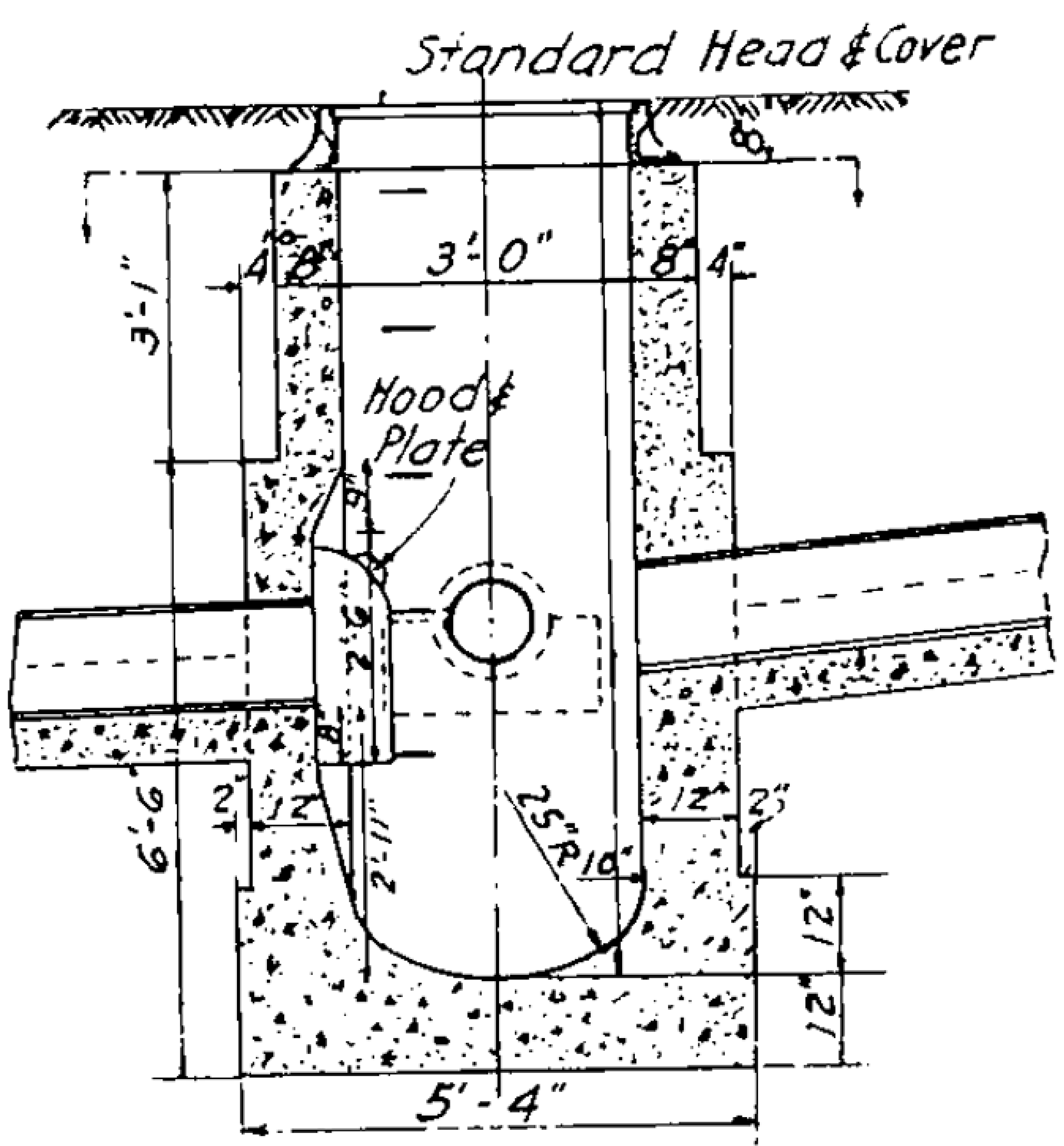
For area of inlet openings use formula on page 5-17.

The required strength of casting to be determined from page 5-19.

Sump Type catch basins to be used only where labor is available for frequent cleaning and where stagnant water is not objectionable. They may be required where flat grades would cause silting up of drainage system.



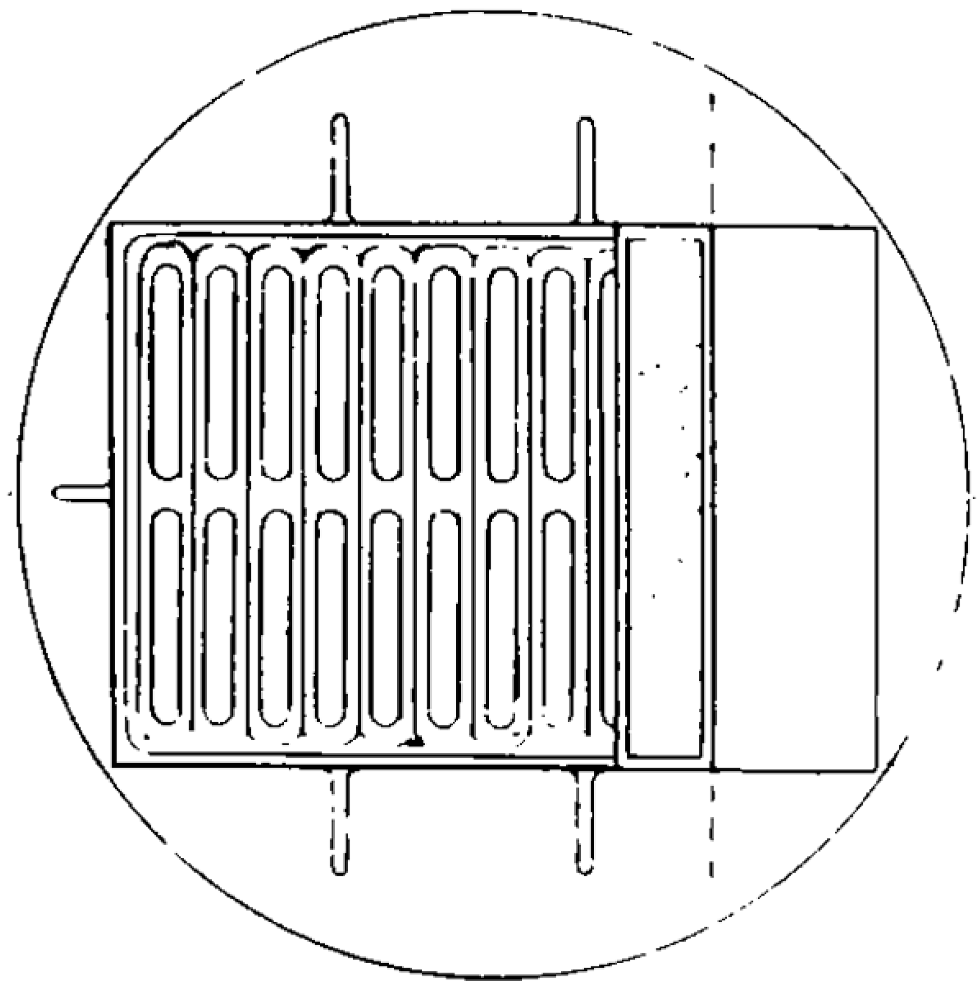
PLAN



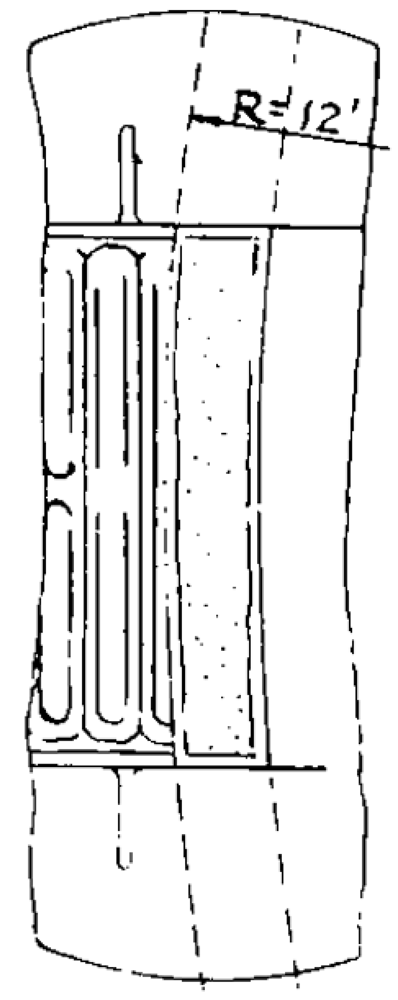
SECTION F-F
TYPICAL CATCH BASIN

Standard in Boro. of Manhattan, N.Y.C.

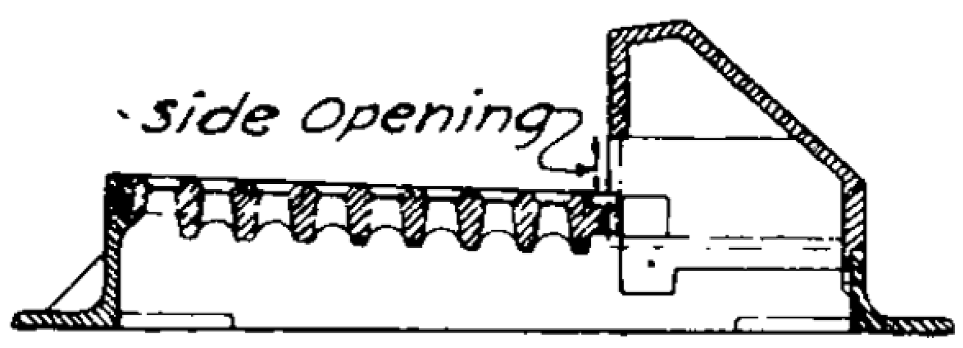
DRAINAGE & SEWERAGE - DETAILS OF INLET COVERS



PLAN



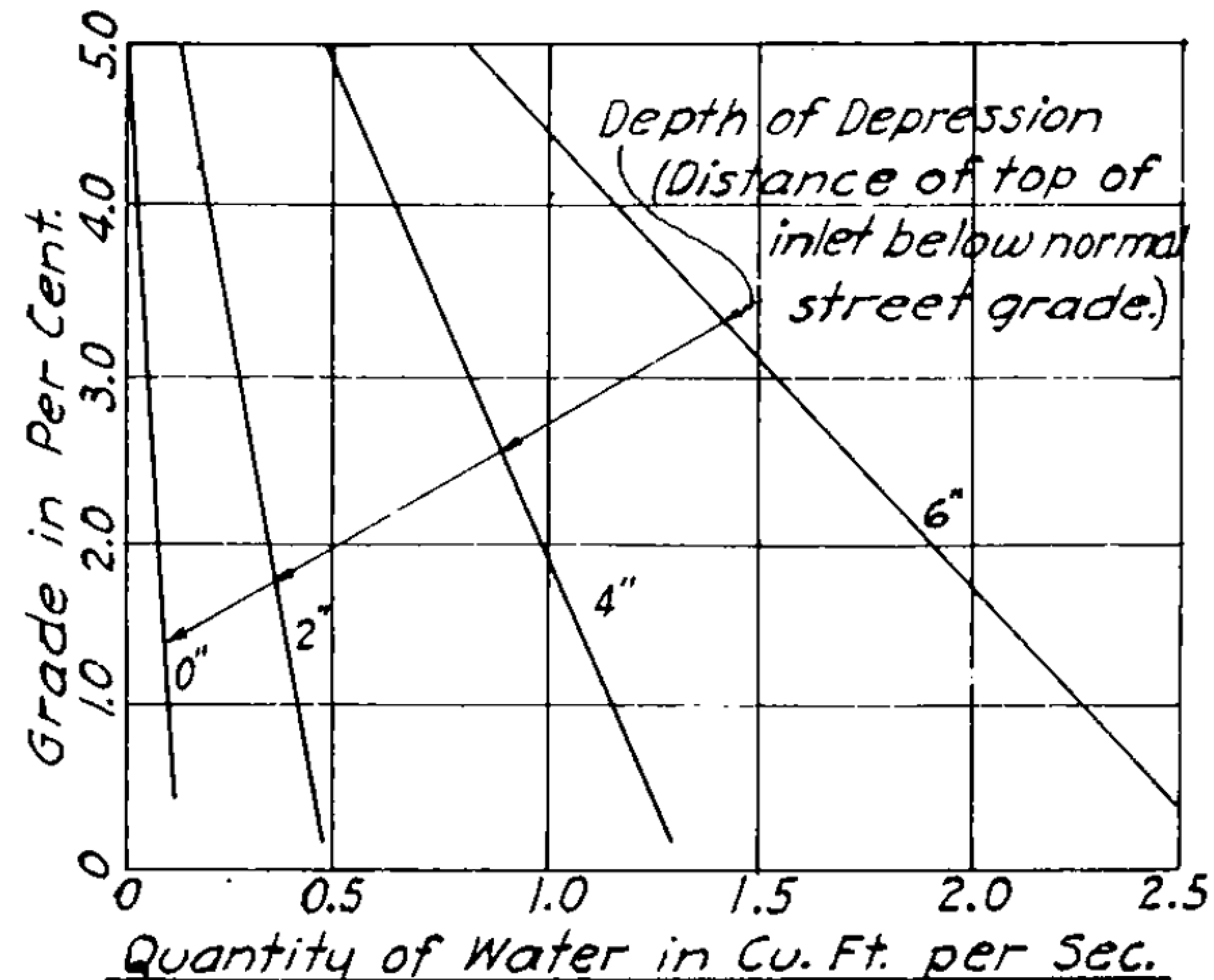
PART PLAN SHOWING CURVED CASTING.



SECTION

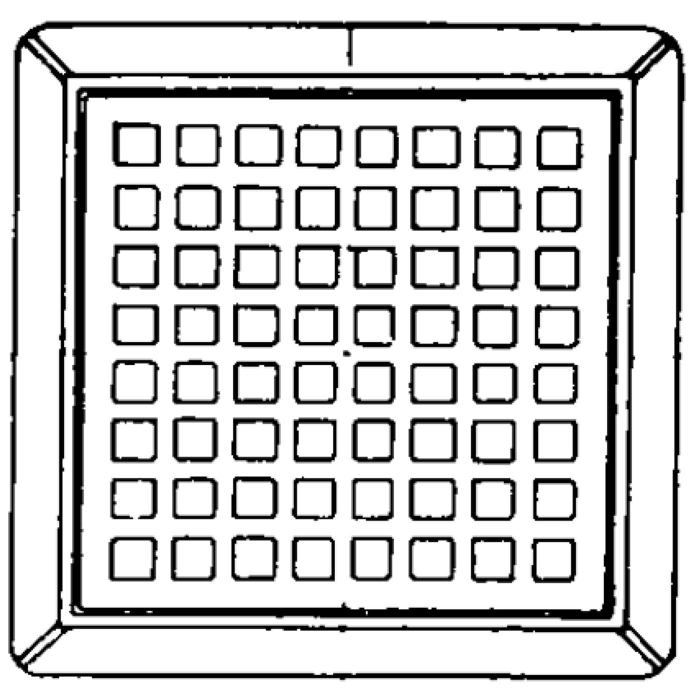
NOTE: To determine the capacity of this type casting, add 'Q' of side opening to 'Q' of grate opening.

TYPICAL CURB INLET OR CATCH BASIN CASTING.

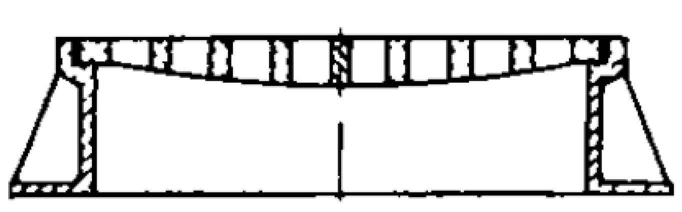


Data for an inlet 4'-6" long and 6" high with water just lapping past. For other size openings the capacities are approximately in proportion.

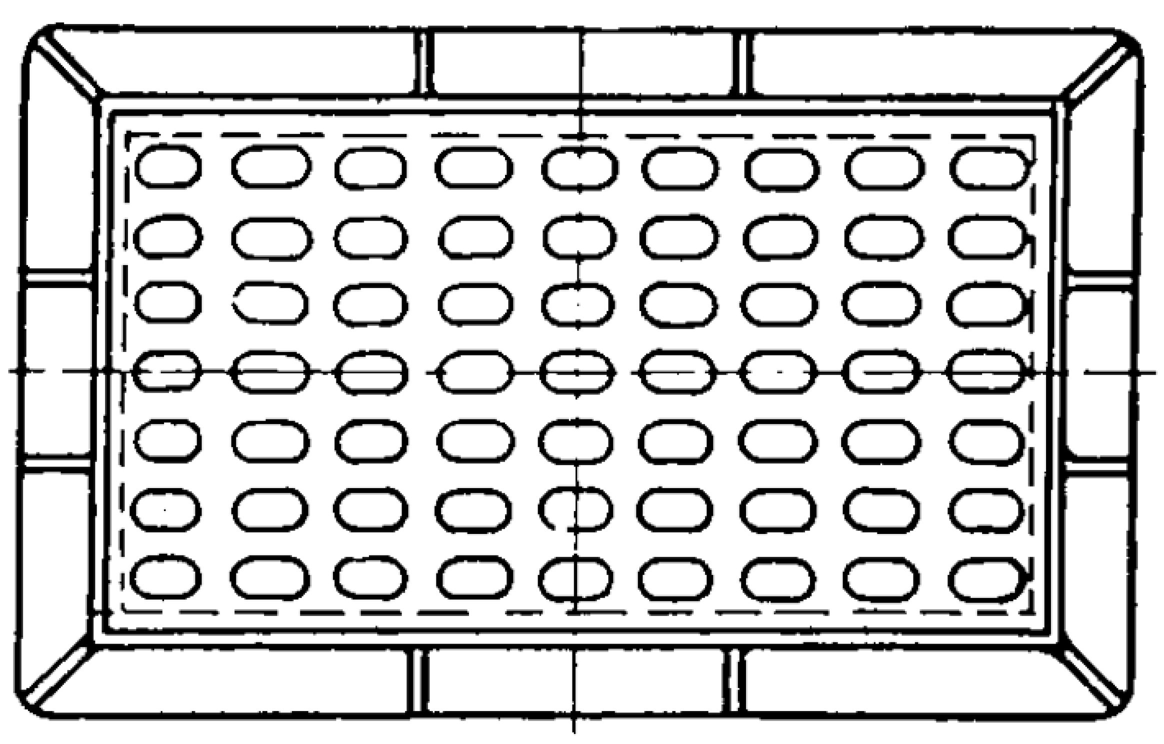
FIG. A.- RELATION BETWEEN STREET GRADES & SIDE INLET CAPACITY FOR VARIOUS DEPTHS OF DEPRESSION.*



PLAN



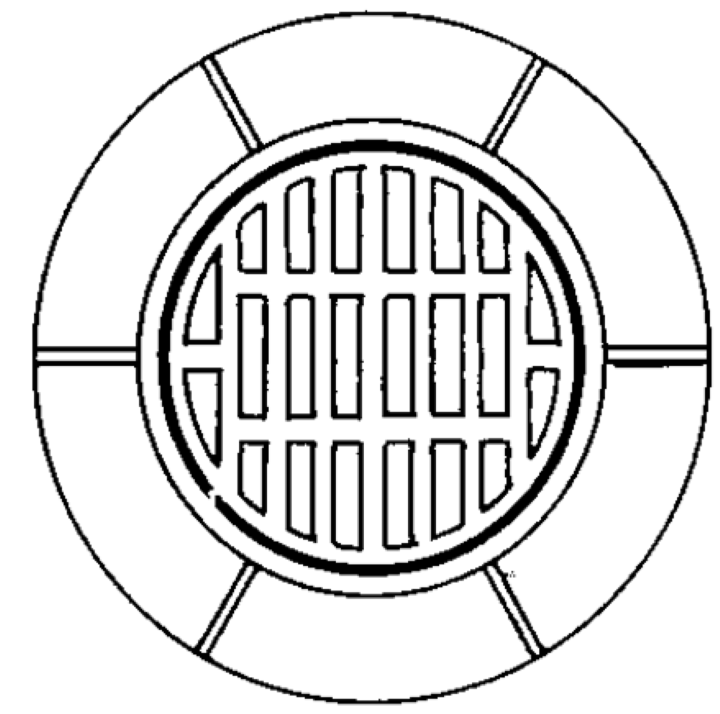
SECTION
WITH PLANE COVER
SQUARE



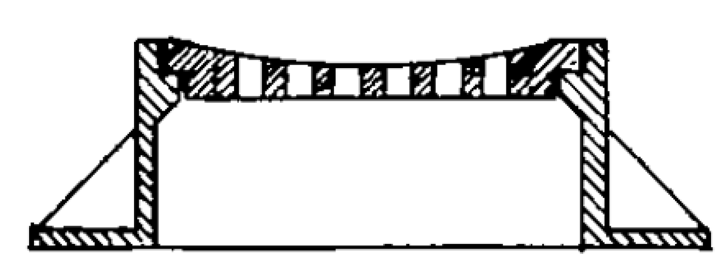
PLAN

SECTION
WITH CONCAVE COVER
RECTANGULAR

TYPICAL ROADWAY INLET CASTINGS.



PLAN



SECTION.

CIRCULAR INLET OR MANHOLE CASTING.

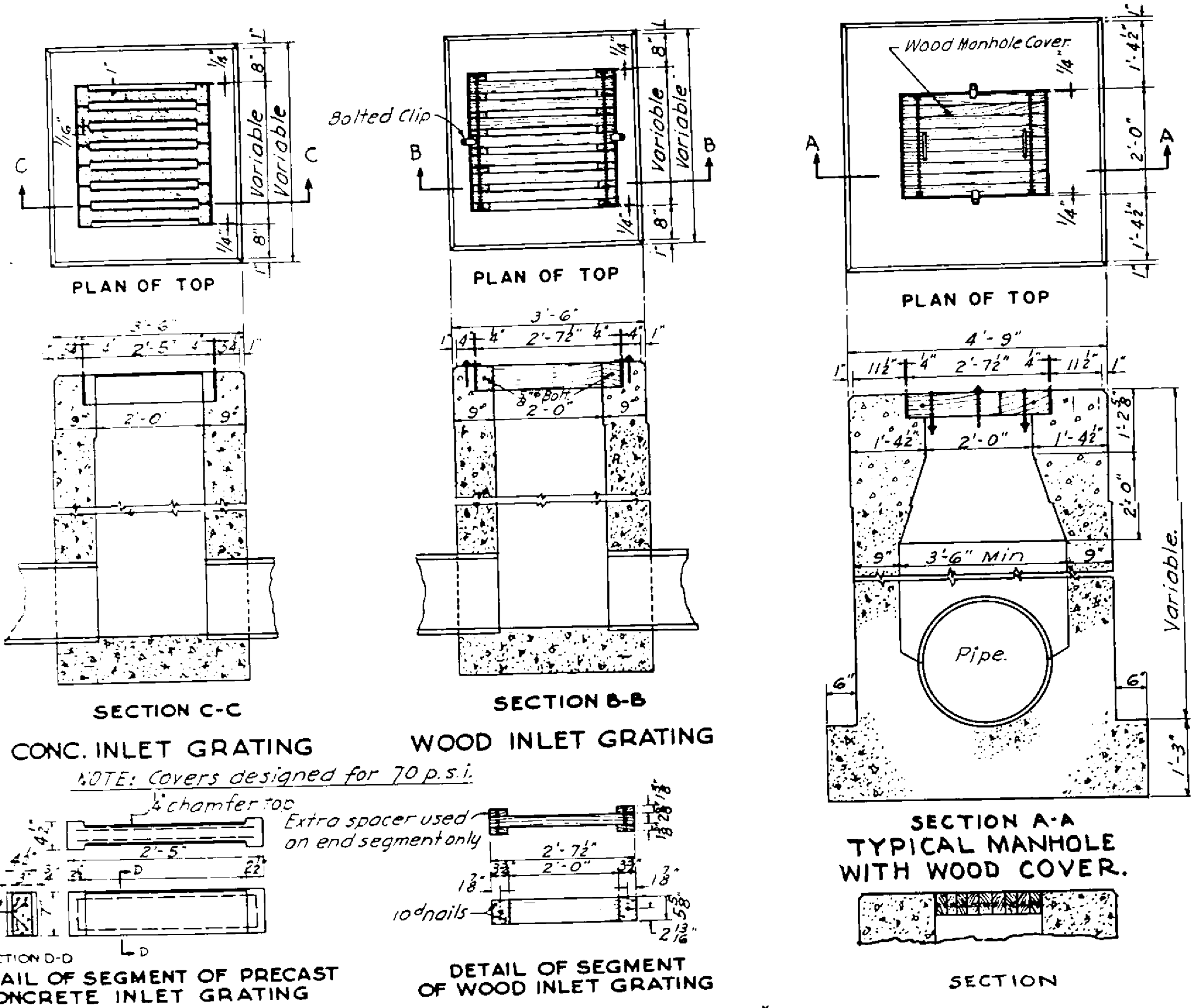
FORMULA FOR DETERMINING THE AREA OF INLET GRATING OPENINGS.

$$Q = cA\sqrt{2gh} \times \text{factor for clogging. (Use } 2/3)$$

Where: Q = Quantity of runoff reaching inlet in cubic feet per second.
c = Orifice coefficient: 0.6 for openings with square edges.
.0.8 " " " rounded "
A = Net area in square ft.
g = 32.2
h = Allowable head on inlet in feet.

*From Municipal & County Engineering 1919 Vol. 57 page 147.

DRAINAGE & SEWERAGE - MANHOLE & INLET COVERS



CONCRETE AND WOOD INLET GRATINGS.*

TABLE A - DESIGN DATA FOR CONCRETE & WOOD INLET GRATINGS.*

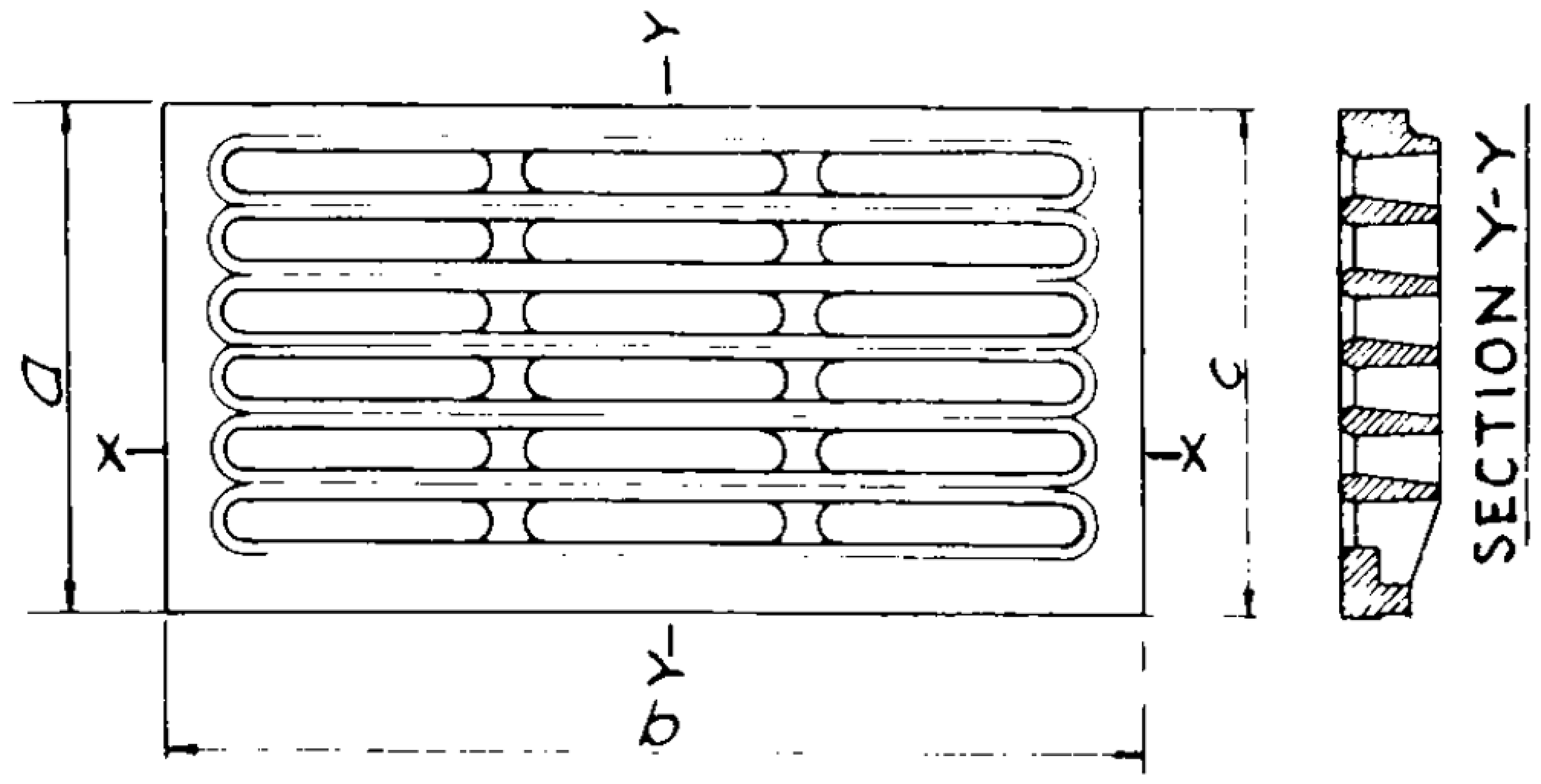
NUMBER OF BARS	CONCRETE: WATERWAY OPENING (SQ.FT.)	CONCRETE: DISCHARGE CU.FT./SEC.	CONCRETE: LENGTH OF GRATE ASSEMBLY (IN INCHES)	WOOD: WATERWAY OPENING (SQ.FT.)	WOOD: DISCHARGE CU.FT./SEC.	WOOD: LENGTH OF GRATE ASSEMBLY (IN INCHES)
5	1.38	2.0	19	1.63	2.3	23
10	2.68	3.9	42	2.98	4.3	44
15	3.98	5.7	64	4.36	6.3	65
20	5.28	7.6	87	5.68	8.2	87
25	6.58	9.5	110	7.04	10.1	108
30	7.88	11.3	133	8.40	12.1	129
35	9.18	13.2	156	9.75	14.0	150
40	10.48	15.1	178	11.10	16.0	171
45	11.79	17.0	201	12.46	17.9	193
50	13.09	18.8	224	13.82	19.9	214

Based on Formula, see Pg. 5-17, where $c = 0.6$; $g = 32.2$; $h = 0.2$.

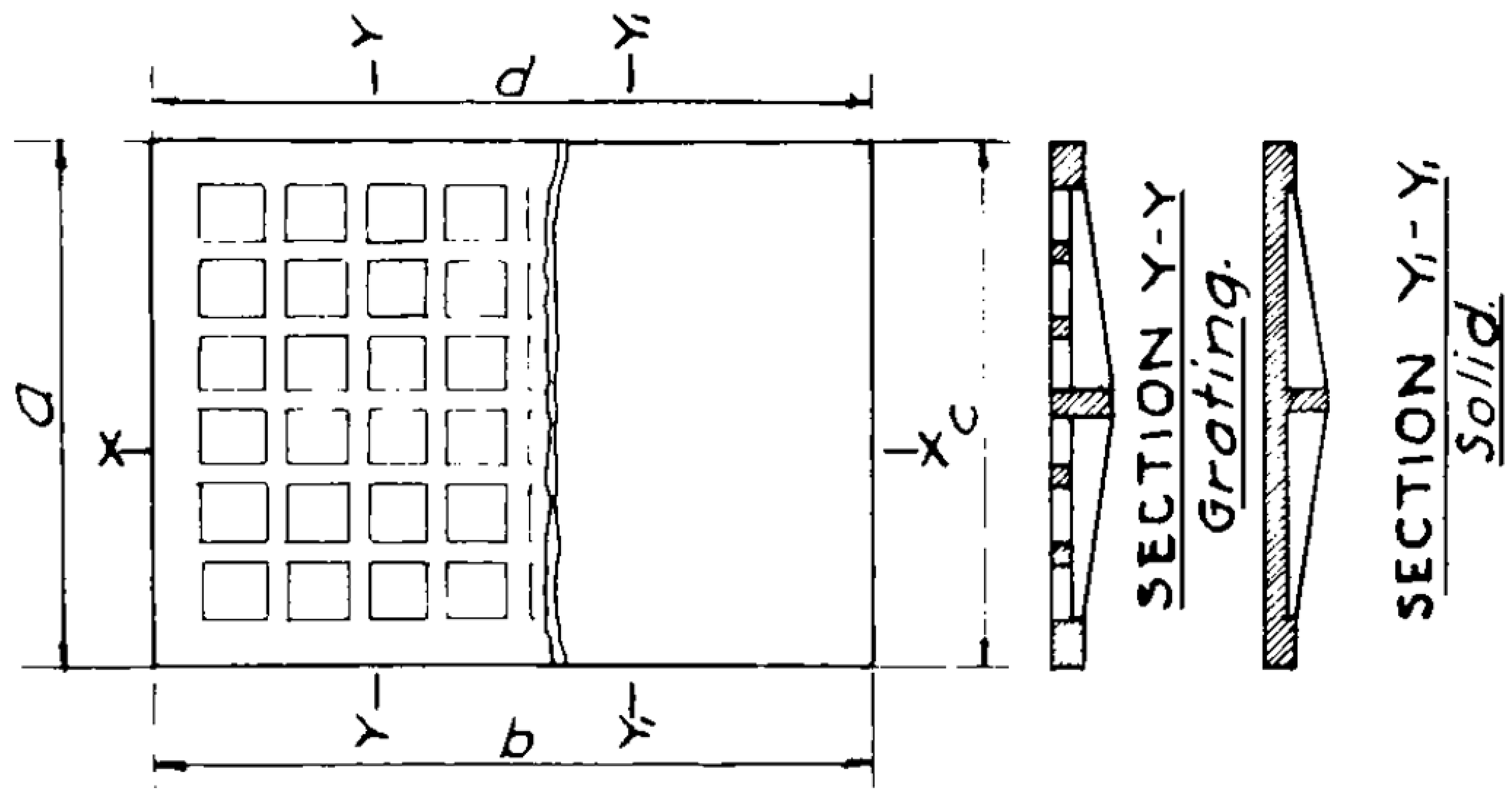
*From Engineering Manual - Chap. XXI, on Airfield Drainage. - War Dept., Corps of Engineers Mar. 1943.

DRAINAGE & SEWERAGE - MANHOLE & CATCH BASIN COVERS

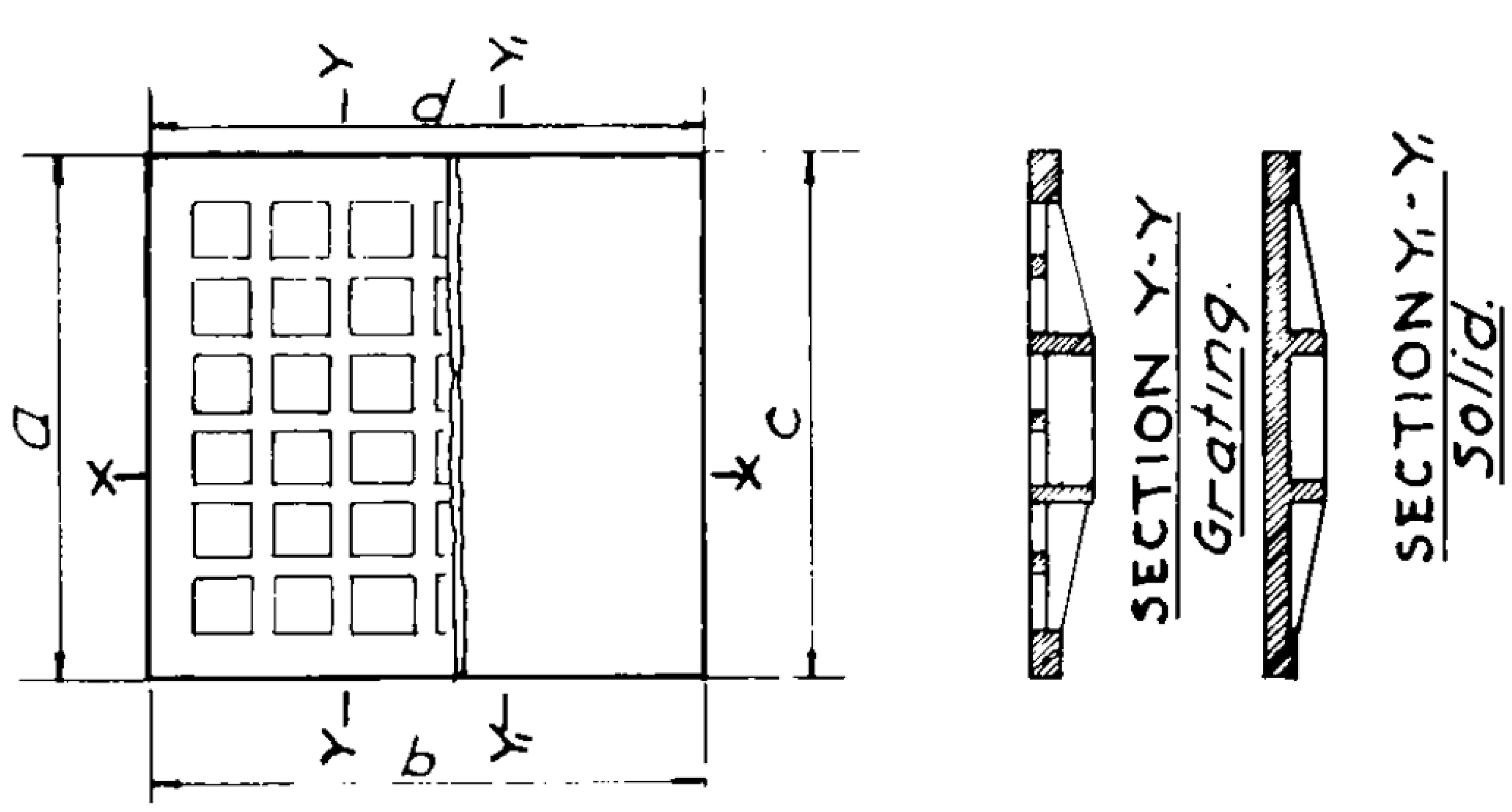
DATA FOR CHECKING STRENGTH OF STOCK COVERS



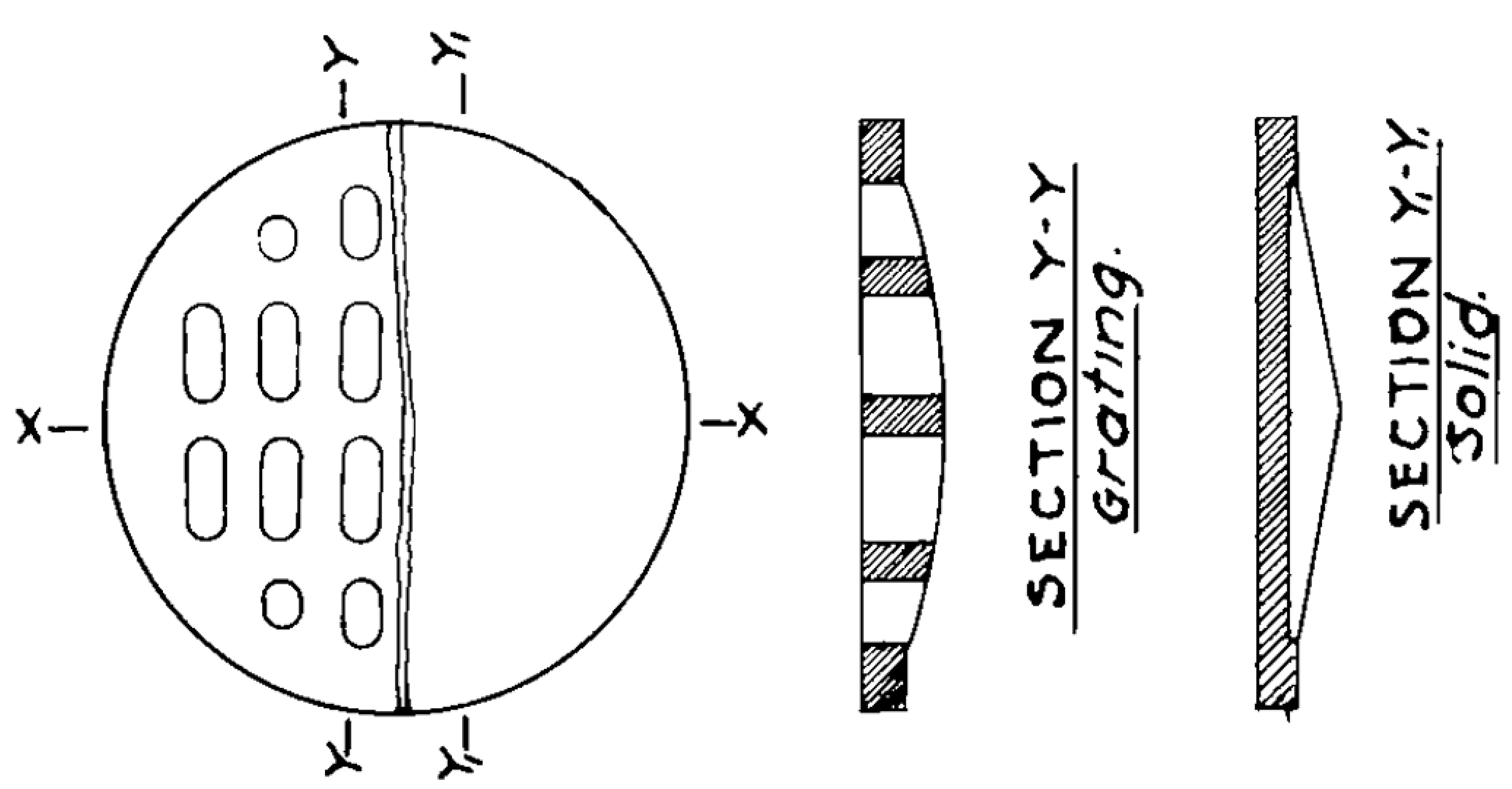
TYPE 1. CURB INLET.



TYPE 2. RECTANGULAR COVER.



TYPE 3. SQUARE COVER.



TYPE 4. CIRCULAR COVER.

REQUIRED SECTION MODULUS, S_x AND S_y, FOR X-X AND Y-Y AXES

TYPE	SIZE IN INCHES	SUPPORT REQUIRED ON SIDES	HEAVY LOADING S_y	HEAVY LOADING S_x	LIGHT LOADING S_y	LIGHT LOADING S_x
1	18 x 24	a, c	17.2	0	10.9	0
	18 x 36	"	28.3	0	17.9	0
	18 x 48	"	41.2	0	25.0	0
	24 x 24	"	17.2	0	10.9	0
	24 x 36	"	28.3	0	17.9	0
	24 x 48	"	41.2	0	25.0	0
2	12 x 24	b, d	0	6.5	0	4.8
	18 x 24	a, b, c, d	5.2	10.7	3.3	6.9
	18 x 30	b, d	0	14.0	0	9.2
	24 x 36	"	0	21.5	0	15.0
	24 x 48	"	0	25.2	0	20.0
	30 x 42	a, b, c, d	8.9	23.7	5.4	18.6
	30 x 48	b, d	0	34.8	0	26.7
	36 x 48	a, b, c, d	12.9	32.5	8.3	25.2
3	24 x 24	a, b, c, d	9.3	9.3	6.1	6.1
	30 x 30	"	13.0	13.0	8.3	8.3
	36 x 36	"	16.8	16.8	10.5	10.5
	42 x 42	"	20.8	20.8	12.7	12.7
	48 x 48	"	24.3	24.3	14.9	14.9
4	DIAM. 24"	PERIPHERY	7.8	7.8	5.3	5.3
	" 30"	"	11.1	11.1	7.2	7.2
	" 36"	"	14.5	14.5	9.2	9.2
	" 42"	"	17.9	17.9	11.2	11.2
	" 48"	"	21.3	21.3	13.2	13.2

Heavy Loading: 12,000 lb. wheel load
65 lb./sq.in. tire pressure.
185 sq.in. loaded area.
Impact + 25 %.

Light Loading: 7,000 lb. wheel load.
60 lb./sq.in. tire pressure.
117 sq.in. loaded area.
Impact + 25 %.

Assumed tensile stress for Cast Iron = 3,000 lb. sq.in.
Required Section Modulus for net section equals total width of cover minus holes if any.
Required Section Moduli for other loads are approximately proportional.

DRAINAGE & SEWERAGE - PIPE DATA-1

PIPE CLASSES & PROPERTIES

INSIDE PIPE DIA. (INCHES)	CONCRETE SEWER PIPE — PLAIN A.S.T.M. SPEC. C-14-41. SHELL THICKNESS (INCHES)	WT. PER LIN. FT. (lbs.)	ULT. STRENGTH 3 EDGE BEARING LBS. PER LIN. FT.	CONCRETE SEWER PIPE — REINFORCED A.S.T.M. SPEC. C-75-41. SHELL THICKNESS (INCHES)	WT. PER LIN. FT. (lbs)	ULT. STRENGTH 3 EDGE BEARING LBS. PER LIN. FT.	CONCRETE CULVERT PIPE — REINFD. STAND. STRENGTH A.S.T.M. SPEC. C-76-41. SHELL THICKNESS* (INCHES)	WT. PER LIN. FT. (lbs.)	ULT. STRENGTH 3 EDGE BEARING LBS. PER LIN. FT.	CONCRETE CULVERT PIPE — REINFD. EXTRA STRENGTH A.S.T.M. SPEC. C-76-41. SHELL THICKNESS† (INCHES)	WT. PER LIN. FT. (lbs.)	ULT. STRENGTH 3 EDGE BEARING LBS. PER LIN. FT.	CORRUGATED METAL PIPE — 16 GAUGE WT. PER LIN. FT. (lbs.)	14 GAUGE WT. PER LIN. FT. (lbs.)	12 GAUGE WT. PER LIN. FT. (lbs.)	10 GAUGE WT. PER LIN. FT. (lbs.)	8 GAUGE WT. PER LIN. FT. (lbs.)
4	9/16		1000														
6	5/8	25	1100										7.6	9.3			
8	3/4	35	1300										9.3	11.4			
10	7/8	48	1400										10.8	13.3	18.5		
12	1	60	1500	2 §	90	1800	2	90	2250				13.3	16.4	22.7		
15	1 1/4	90	1750	2 1/4 §	125	2000	2 1/4	125	2625				15.8	19.5	27.0		
18	1 1/2	120	2000	2 1/2 §	160	2200	2 1/2	160	3000				18.3	22.5	31.2	39.7	
21	1 3/4	190	2200	2 3/4 §	205	2400							21.0	26.0	35.9	45.7	
24	2 1/8	225	2400	2 5/8 *	225	2400	3	260	3000	3	320	4000		31.7	43.9	55.9	
30				3 *	315	2700	3 1/2	370	3375	3 1/2	470	5000		37.9	52.4	66.7	81.1
36				3 3/8 *	450	3000	4	520	4050	4	600	6000		44.4	61.5	78.3	95.1
42				3 3/4 *	560	3200	4 1/2	680	4725	4 1/2	750	7000		50.5	70.0	89.1	108.3
48				4 1/4 *	720	3400	5	850	5400	5	1000	8000		57.8	80.1	102.0	123.9
54				4 5/8 *	880	3700	5 1/2	1050	5850	5 1/2	1050	9000			88.2	112.3	136.4
60				5 *	1060	4000	6	1280	6000	6	1280	9000			96.6	123.1	149.5
66				5 3/8 *	1250	4250	6 1/2	1480	6300	6 1/2	1480	9500			105.1	133.9	162.6
72				5 3/4 *	1560	4500	7	1835	6600	7	1835	9900				156.6	190.3
84				8 §	2000		8	2300		8	2300						

* Conc. 3500 p.s.i. § Conc. 3000 p.s.i. † Conc. 4500 p.s.i.
Ultimate strength given for reinforced concrete pipe is A.S.T.M. "first crack" strength.
Standard laying length - 4 ft.
Weights per lin. ft. furnished by Universal Concrete Pipe Co.

Furnished in any length in multiples of 2 ft.
Data furnished for Armco. Pipe by Shelt Co. Elmira, N.Y.

DRAINAGE & SEWERAGE — PIPE DATA-2

PIPE CLASSES & PROPERTIES

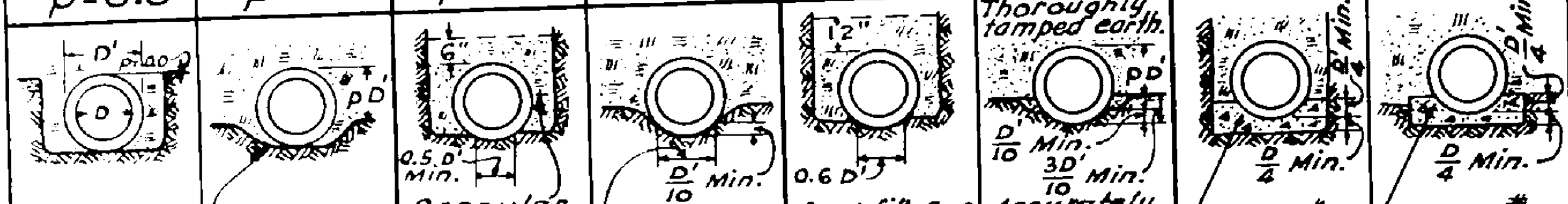
INSIDE PIPE DIA. (INCHES)	VITRIFIED CLAY SALT GLAZED — DOUBLE STRENGTH: SHELL THICKNESS (INCHES)	WT. PER LIN. FT. (lbs.)	ULT. STRENGTH 3 EDGE BEARING LBS. PER LIN. FT.	EXTRA STRENGTH: SHELL THICKNESS (INCHES)	WT. PER LIN. FT. (lbs.)	ULT. STRENGTH 3 EDGE BEARING LBS. PER LIN. FT.	CEMENT-ASBESTOS SEWER PIPE (TRANSITE) — CLASS 1: SHELL THICKNESS (INCHES)	WT. PER LIN. FT. (lbs.)	ULT. STRENGTH 3 EDGE BEARING LBS. PER LIN. FT.	CLASS 2: SHELL THICKNESS (INCHES)	WT. PER LIN. FT. (lbs.)	ULT. STRENGTH 3 EDGE BEARING LBS. PER LIN. FT.	CLASS 3: SHELL THICKNESS (INCHES)	WT. PER LIN. FT. (lbs.)	ULT. STRENGTH 3 EDGE BEARING LBS. PER LIN. FT.	CLASS 4: SHELL THICKNESS (INCHES)	WT. PER LIN. FT. (lbs.)	ULT. STRENGTH 3 EDGE BEARING LBS. PER LIN. FT.
4	1/2	8	1000				0.39	4.9	4125									
6	5/8	14.5	1000	11/16	15.5	2000	0.42	7.9	2880									
8	3/4	23.0	1000	13/16	24.0	2000	0.48	11.9	3100									
10	7/8	31.5	1100	1	36.5	2000	0.50	15.3	2580	0.56	17.7	3690	0.65	21.0	4920			
12	1	43.5	1200	1 1/4	55.5	2250	0.54	19.9	2370	0.64	23.6	3850	0.74	28.6	5100			
14							0.58	24.6	2200	0.73	31.0	3920	0.84	37.0	5150			
15	1 1/4	67.5	1370	1 5/8	89.5	2750												
16							0.62	30.2	2120	0.82	40.6	4050	0.94	47.8	5280			
18	1 1/2	96.0	1665	1 7/8	116.0	3300	0.65	35.5	2030	0.90	51.0	4140	1.03	58.0	5360	1.12	66.0	6340
20							0.69	41.7	2290	0.94	57.5	4280	1.13	70.0	5850	1.25	84.0	7100
21	1 3/4	137.0	1995	2 1/4	180.0	3850												
24	2	171.5	2400	2 1/2	218.0	$\boxed{4400}$	0.75	54.3	2340	1.06	77.6	$\boxed{4550}$	1.31	100.0	7050	1.45	110.0	8600
30	2 1/2	270.0	3170	3 1/8	344.0	5000	0.96	86.8	2980	1.24	113.2	5000	1.64	155.0	8180	1.85	175.0	10450
36	2 3/4	390.0	3900	3 1/2	505.0	6000	1.15	124.8	3500	1.41	154.3	5400	1.93	215.0	9700	2.18	248.0	12300

Laying lengths:
Double strength - 2, 2½ or 3 ft.
Extra strength - 2, 2½, 3 or 4 ft.
Ult. strengths and shell thicknesses as required by A.A.S.H.O. Spec. M. 65-42, & A.S.T.M. Spec. C13-40.
Weights per lin. ft. from Handbook of Vitrified Clay Sewer Pipe, Clay Sewer Pipe Assoc., Inc.

Standard laying length - 13 ft.
Furnished only in straight lengths.
Cast-Iron fittings recommended for branch connections.
Ultimate strengths determined by tests made in accordance with procedure of A.S.T.M.
All data furnished by Johns-Manville Corp.

DRAINAGE & SEWERAGE - LOADING ON PIPES

TABLE A - REQUIRED ULTIMATE STRENGTH, LBS. PER LIN. FT., OF PIPE FOR VARIOUS DEPTHS UNDER H-20 HIGHWAY LOADING.



DEPTH OF COVER OVER PIPE (feet)	BEDDING CONDITIONS: IMPERMISSIBLE		ORDINARY		FIRST CLASS		CONCRETE CRADLE	
	p=0.0	p=0.7	p=0.0	p=0.7	p=0.0	p=0.7	p=0.0	p=0.7
	Backfill untamped.	Not shaped to fit pipe.	Granular materials shovel placed and tamped.	Accurately shaped to fit pipe.	Backfill carefully tamped in thin layers.	Thoroughly tamped earth. Accurately shaped to fit pipe.	2000 # Concrete.	2000 # concrete.
2	2430 D	2490 D	2280 D	2320 D	2250 D	2260 D	2190 D	2190 D
3	2060 D	2190 D	1840 D	1300 D	1770 D	1820 D	1700 D	1690 D
4	1880 D	2040 D	1580 D	1670 D	1500 D	1560 D	1400 D	1400 D
5	1760 D	2180 D	1390 D	1640 D	1290 D	1480 D	1160 D	1240 D
6	1820 D	2220 D	1380 D	1600 D	1260 D	1440 D	1100 D	1160 D
7	1900 D	2380 D	1390 D	1660 D	1240 D	1450 D	1070 D	1140 D
8	2050 D	2550 D	1460 D	1740 D	1290 D	1510 D	1090 D	1160 D
9	2200 D	3030 D	1530 D	1990 D	1340 D	1720 D	1110 D	1290 D
10	2350 D	3240 D	1610 D	**2130 D**	1400 D	1820 D	1150 D	1320 D
12	2650 D	3780 D	1770 D	2430 D	1520 D	2040 D	1210 D	1450 D
14	3020 D	4340 D	2000 D	2830 D	1710 D	2360 D	1350 D	1660 D
16	3330 D	5010 D	2210 D	3170 D	1890 D	2650 D	1500 D	1860 D
18	3780 D	5780 D	2470 D	3650 D	2100 D	3030 D	1640 D	2090 D
20	4170 D	6300 D	2700 D	3970 D	2290 D	3400 D	1790 D	2270 D

For depth greater than 20 ft., use Table B below. D = inside diameter in feet.

EXAMPLE: Assume 24"φ pipe, depth 10 ft., ordinary bedding p = 0.7
Table A above: Ultimate strength per lin. ft. 2130 D = 2130 × 2 = 4260.
From page 5-21 select vitrified clay extra strength pipe or Class 2, Transite pipe.

TABLE B - MAX. HEIGHT IN FEET OF FILL OVER PIPE (NO LIVE LOAD).*

ULT. STRENGTH 3 EDGE BEARING LBS/L.F.	BEDDING CONDITIONS: IMPERMISSIBLE		ORDINARY		FIRST CLASS		CONCRETE CRADLE	
	p=0.0	p=0.7	p=0.0	p=0.7	p=0.0	p=0.7	p=0.0	p=0.7
1200 D	6.0	4.5	9.0	7.0	11.0	8.0	14.0	11.5
1500 D	7.5	5.5	11.5	8.5	13.5	10.0	18.0	14.0
1800 D	9.0	6.5	14.0	10.0	16.5	11.5	21.5	17.0
2000 D	10.0	7.0	15.5	11.0	18.0	13.0	23.5	18.5
3000 D	14.5	10.0	23.0	16.0	27.0	19.0	35.5	27.0
4000 D	20.0	13.0	30.5	20.5	36.5	24.5	47.5	36.0

NOTES FOR TABLES A & B: - In rock excavations an earth cushion less than 8" is classed as IMPERMISSIBLE bedding. ORDINARY & FIRST CLASS beddings require earth cushions of 8" minimum.

The values shown in the columns headed p=0.7 should be used for projection ratios from 0.3 to 0.9 and those shown in columns headed p=0.0 should be used for installations where the pipe is installed in a trench dug to a depth at least equal to the outside diameter of the pipe.

There is a difference of opinion in regard to the practicability of dishing the bed as called for under ordinary and first class conditions.

* From American Highway Practice by Laurence I. Hewes.

DRAINAGE & SEWERAGE - BASES OF DESIGN

DETERMINATION OF SEWAGE FLOW BASED ON RULES & REGULATIONS OF NEW YORK STATE DEPARTMENT OF HEALTH 1940

ITEM	BASIS OF DESIGN
Future Population	30-50 years from time of construction of system.
Average Daily Flow	100 gallons per capita per day.
Laterals & Submains Flowing Full	400 gallons per capita per day.
Mains, Trunks and Outfalls Flowing Full	250 gallons per capita per day.
Industrial Plant Wastes	Add additional allowance depending on process.
Minimum Slope of Pipe	Sufficient to give mean velocity of 2 feet per second when pipe is flowing full or half full.
Maximum Velocities	Common Brick 6 ft. per sec., Concrete 8 f.p.s., Vitrified pipe 15 f.p.s., Vitrified brick 20 f.p.s.
Manhole Spacing	At all changes of grade, alignment and size of pipe. Not more than 300 foot intervals.
Minimum Size of Street Sewers	8 inches diameter.
Inverted Siphons - Minimum Pipe Size	6 inches diameter.
Inverted Siphons - Minimum No. of Pipes	2
Inverted Siphons - Minimum Velocity	3 ft. per sec. for sep. systems - 5 ft. per sec. for combined systems.
Pumping Stations - Min. No. of Pumps	3 in main plants and 2 in small stations.
Pumping Stations - Motive Power	Available from at least 2 independent sources.
Pumping Stations - Suction & Discharge	Minimum size 4 inches diameter.

Metcalf and Eddy suggest an allowance for infiltration into the sewerage system of 1000 to 2000 gallons per acre per day when ground water is encountered above the sewer line.

SUGGESTED FORM FOR SANITARY SEWER DESIGN COMPUTATIONS*

SANITARY COMPUTATIONS

Computed by:______ "n" = 0.015

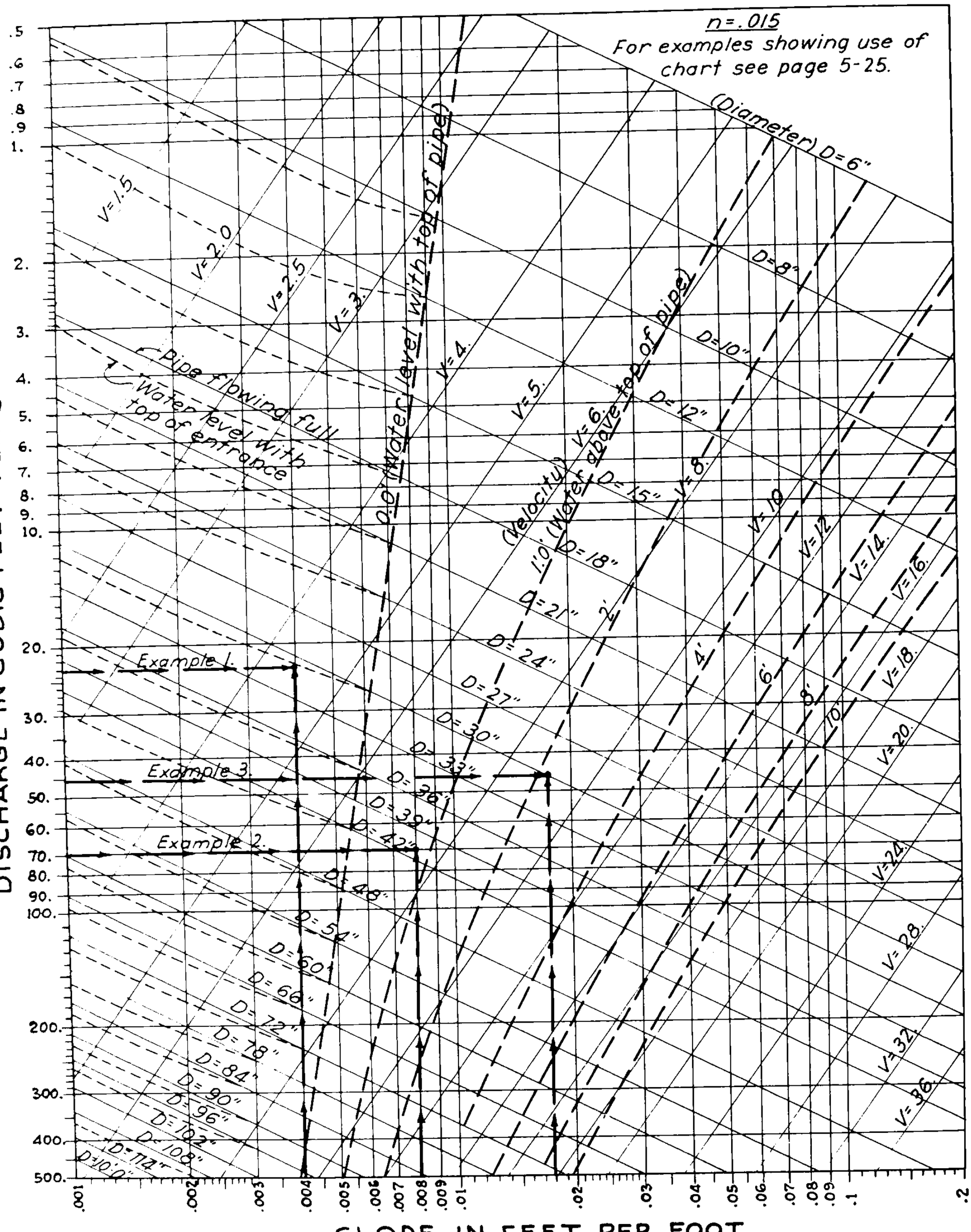
Checked by:______ Location____________ Density of Population = 30/acre.

Date:_________ Sheet ___ of _______

SEWER LOCATION			TRIBUTARY AREA (ACRES)		MAX. RATE OF SEWAGE FLOW			DESIGN				PROFILE				
Street	From man-hole No.	To man-hole No.	Incre-ment	Total	Rate per acre, g.p.d.	Total m.g.d.	Total c.f.s.	Diam. inches	Slope ft./ft.	Capacity when full c.f.s.	Vel. when full f.p.s.	Length feet	Fall feet	Other losses feet	Invert elev. upper end	Invert elev. lower end
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Third	10	11	43.3	43.3	12,000	0.52	0.80	10	.0045	1.12	2.2	325	1.46	0.00	95.33	93.87
Third	11	12	14.2	57.5	12,000	0.69	1.07	10	.0082	1.60	2.8	400	3.28	0.08	93.79	90.51
Chestnut	12	13	10.0	67.5	12,000	0.81	1.25	12	.0036	1.75	2.2	350	1.26	0.21	90.30	89.04

* Adapted from Davis, Handbook of Applied Hydraulics, McGraw-Hill.

DRAINAGE & SEWERAGE — PIPE CAPACITIES*-1



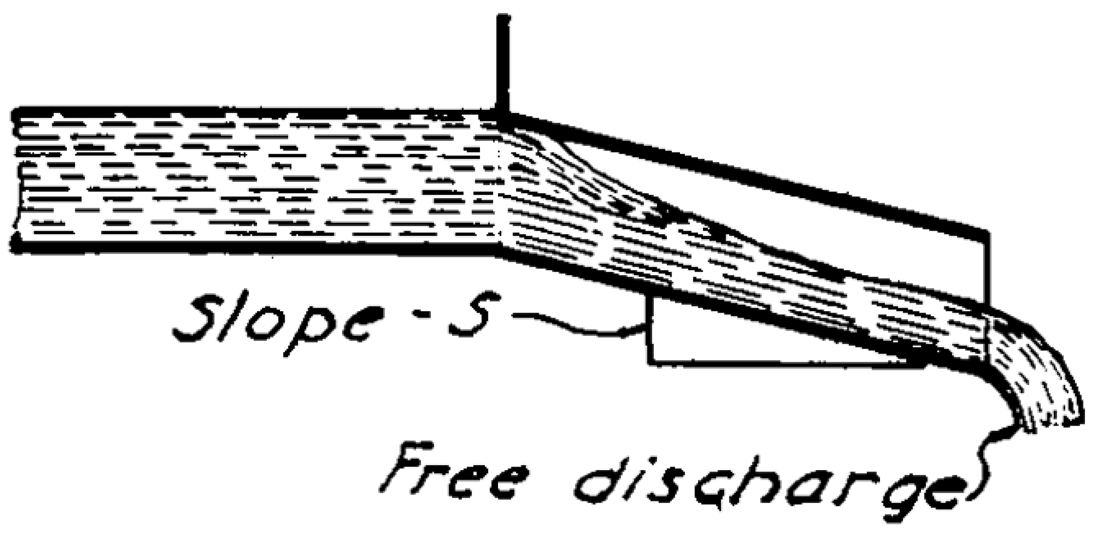
* Adapted from Gohi Culvert Manufacturing Corp.

DRAINAGE & SEWERAGE - PIPE CAPACITIES-2

EXAMPLES SHOWING USE OF CHART PG. 5-24

Capacities and velocities in chart page 5-24 are for $n = 0.015$. For other values of n, given on page 5-26, multiply charted values by $\frac{n}{0.015}$.

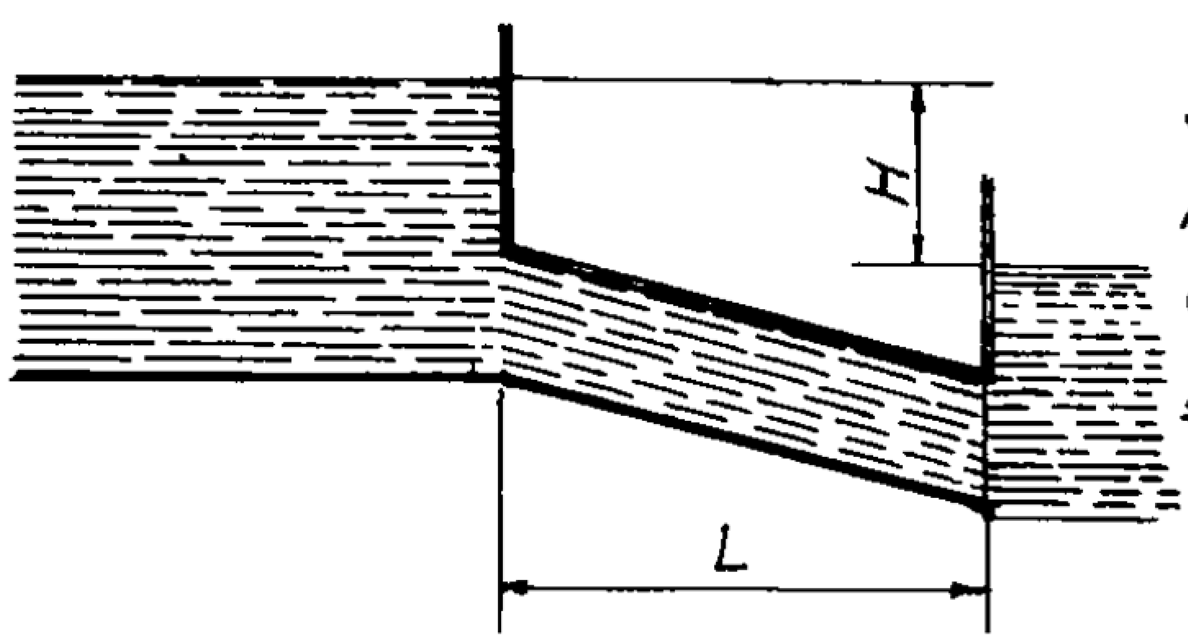
Case 1.



Dash lines to left of 0-0 line give values when water is level with top of pipe at entrance. Velocity of approach and entrance loss neglected.

Example 1. - Given: $Q = 23$ c.f.s.; $S = 0.004$; $n = 0.015$.
Required: D and V.
Solution: Enter Chart at 23 c.f.s.; read D=30" at S=0.004, and V= 4.4 Ft./Sec.

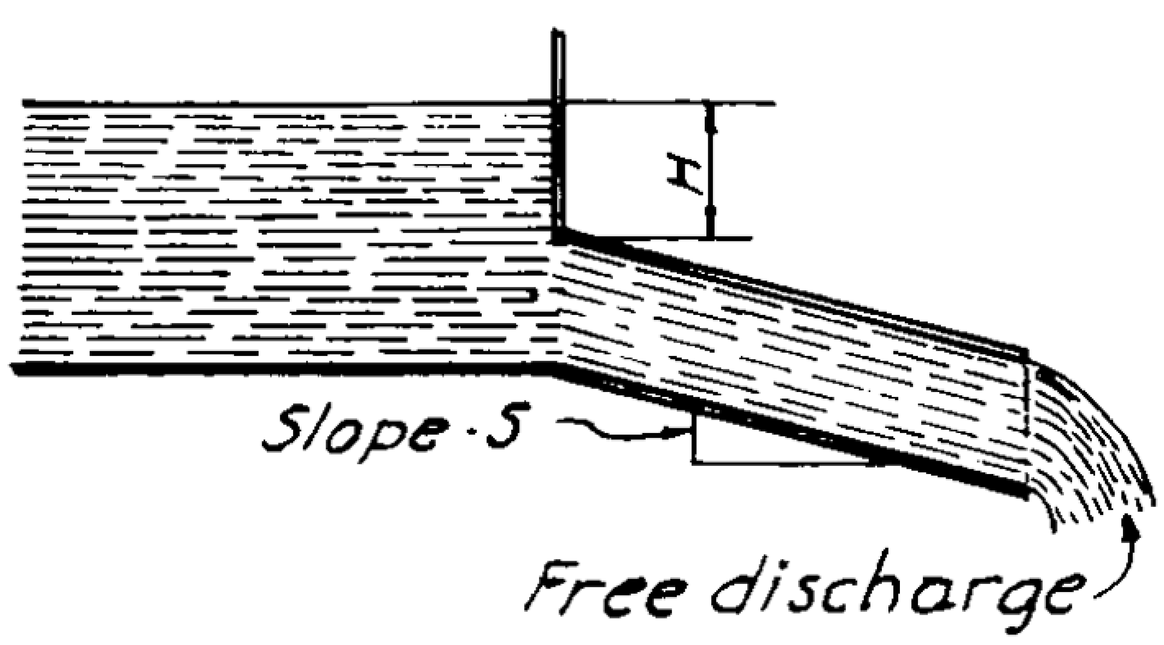
Case 2.



Solid D lines give values by Manning Formula (see page 5-27) for pipe flowing full. In this case $S = \frac{H}{L}$ = slope of hydraulic gradient. Minor losses neglected.

Example 2. - Given: $Q = 70$ c.f.s.; $H = 4$ ft.; $L = 500$ ft. $\therefore S = \frac{H}{L} = 0.008$
Required: D and V.
Solution: Enter Chart at 70 c.f.s. intersect. S=0.008. Read D=42" (nearest adequate size).
V= 7.5 Ft./Sec.

Case 3.



Dash lines to right of 0-0 line indicate limits of capacities with inlets submerged to depths shown, from orifice formula $Q = a \times 0.62\sqrt{2gh}$

Example 3. - Given: $Q = 46$ c.f.s.; $S = 0.018$.
Required: D with a back up H not more than 3 ft.
Solution: Enter Chart at 46 c.f.s. intersect. S=0.018 - Read D = 30" (H= 2.3 Ft.).

Notation:

- Q = Discharge in cubic feet per second.
- V = Velocity of flow in feet per second.
- S = Slope or hydraulic gradient.
- H = Hydraulic head.
- D = Diameter of pipe.
- L = Length of pipe.
- n = Coefficient of roughness.
- g = Acceleration of gravity = 32.16.

DRAINAGE & SEWERAGE-HYDRAULIC COMPUTATION-1

TABLE A-VALUES OF n, TO BE USED WITH KUTTER OR MANNING FORMULAS.†

SURFACE	CONDITION			
	BEST	GOOD	FAIR	BAD
Uncoated cast-iron pipe	0.012	0.013	0.014	0.015
Coated cast-iron pipe	0.011	0.012*	0.013*	
Commercial wrought-iron pipe, black	0.012	0.013	0.014	0.015
Commercial wrought-iron pipe, galvanized	0.013	0.014	0.015	0.017
Smooth brass and glass pipe	0.009	0.010	0.011	0.013
Smooth lockbar and welded OD pipe	0.010	0.011*	0.013*	
Riveted and spiral steel pipe	0.013	0.015*	0.017*	
Vitrified sewer pipe	{0.010 / 0.011}	0.013*	0.015	0.017
Common clay drainage tile	0.011	0.012*	0.014*	0.017
Glazed brickwork	0.011	0.012	0.013*	0.015
Brick in cement mortar, brick sewers	0.012	0.013	0.015*	0.017
Neat cement surfaces	0.010	0.011	0.012	0.013
Cement-mortar surfaces	0.011	0.012	0.013*	0.015
Concrete pipe	0.012	0.013	0.015*	0.016
Wood-stave pipe	0.010	0.011	0.012	0.013
Plank flumes:				
Planed	0.010	0.012*	0.013	0.014
Unplaned	0.011	0.013*	0.014	0.015
With battens	0.012	0.015*	0.016	
Concrete-lined channels	0.012	0.014*	0.016*	0.018
Cement-rubble surface	0.017	0.020	0.025	0.030
Dry rubble surface	0.025	0.030	0.033	0.035
Dressed ashlar surface	0.013	0.014	0.015	0.017
Semicircular metal flumes, smooth	0.011	0.012	0.013	0.015
Semicircular metal flumes, corrugated	0.0225	0.025	0.0275	0.030
Canals and ditches:				
Earth, straight and uniform	0.017	0.020	0.0225*	0.025
Rock cuts, smooth and uniform	0.025	0.030	0.033*	0.035
Rock cuts, jagged and irregular	0.035	0.040	0.045	
Winding sluggish canals	0.0225	0.025*	0.0275	0.030
Dredged earth channels	0.025	0.0275*	0.030	0.033
Canals with rough stony beds, weeds on earth banks	0.025	0.030	0.035*	0.040
Earth bottom, rubble sides	0.028	0.030¹	0.033*	0.035
Natural stream channels:				
1. Clean, straight bank, full stage, no rifts or deep pools	0.025	0.0275	0.030	0.033
2. Same as (1), but some weeds and stones	0.030	0.033	0.035	0.040
3. Winding, some pools and shoals, clean	0.033	0.035	0.040	0.045
4. Same as (3), lower stages, more ineffective slope and sections	0.040	0.045	0.050	0.055
5. Same as (3), some weeds and stones	0.035	0.040	0.045	0.050
6. Same as (4), stony sections	0.045	0.050	0.055	0.060
7. Sluggish river reaches, rather weedy or with very deep pools	0.050	0.060	0.070	0.080
8. Very weedy reaches	0.075	0.100	0.125	0.150

Note: New Cement - Asbestos Pipe, use 0.010.

* *Values commonly used in designing.*

† *Adapted from Handbook of Applied Hydraulics by C.V. Davis, Table compiled by R.E. Horton.*

DRAINAGE & SEWERAGE - HYDRAULIC COMPUTATION - 2

$$Q = a \times \frac{1.486}{n} \times R^{2/3} \times S^{1/2}$$

$$V = \frac{1.486}{n} \times R^{2/3} \times S^{1/2}$$

MANNING FORMULA (FLOW IN PIPES OR CHANNELS)

For values of n see Table. A, page 5-26.

EXAMPLE: Given: existing waterway illustrated in Fig. A, page 5-31, assuming fairly straight banks with some weeds and stones, $a = 90$ sq. ft., $p = 38$ ft., $s = 0.0012$. Required: Q and V.

SOLUTION: $n = 0.035$ from Table. A, page 5-26, $R = \frac{90}{38} = 2.37$, $R^{2/3} = 1.777$ from Table A below, $S^{1/2} = 0.03464$ from Table B below.

Therefore:- $Q = 90 \times \frac{1.486}{0.035} \times 1.777 \times 0.03464 = 235$ c.f.s.

$V = \frac{235}{90} = 2.6$ feet per second.

TABLE A - VALUES OF $R^{2/3}$.*

R	00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.000	.046	.074	.097	.117	.136	.153	.170	.186	.201
.1	.215	.229	.243	.256	.269	.282	.295	.307	.319	.331
.2	.342	.353	.364	.375	.386	.397	.407	.418	.428	.438
.3	.448	.458	.468	.477	.487	.497	.506	.515	.525	.534
.4	.543	.552	.561	.570	.578	.587	.596	.604	.613	.622
.5	.630	.638	.647	.655	.663	.671	.679	.687	.695	.703
.6	.711	.719	.727	.735	.743	.750	.758	.765	.773	.781
.7	.788	.796	.803	.811	.818	.825	.832	.840	.847	.855
.8	.862	.869	.876	.883	.890	.897	.904	.911	.918	.925
.9	.932	.939	.946	.953	.960	.966	.973	.980	.987	.993
1.0	1.000	1.007	1.013	1.020	1.027	1.033	1.040	1.046	1.053	1.059
1.1	1.065	1.072	1.078	1.085	1.091	1.097	1.104	1.110	1.117	1.123
1.2	1.129	1.136	1.142	1.148	1.154	1.160	1.167	1.173	1.179	1.185
1.3	1.191	1.197	1.203	1.209	1.215	1.221	1.227	1.233	1.239	1.245
1.4	1.251	1.257	1.263	1.269	1.275	1.281	1.287	1.293	1.299	1.306
1.5	1.310	1.316	1.322	1.328	1.334	1.339	1.345	1.351	1.357	1.362
1.6	1.368	1.374	1.379	1.385	1.391	1.396	1.402	1.408	1.413	1.419
1.7	1.424	1.430	1.436	1.441	1.447	1.452	1.458	1.463	1.469	1.474
1.8	1.480	1.485	1.491	1.496	1.502	1.507	1.513	1.518	1.523	1.529
1.9	1.534	1.539	1.545	1.550	1.556	1.561	1.566	1.571	1.577	1.582
2.0	1.587	1.593	1.598	1.603	1.608	1.613	1.619	1.624	1.629	1.634
2.1	1.639	1.645	1.650	1.655	1.660	1.665	1.671	1.676	1.681	1.686
2.2	1.691	1.697	1.702	1.707	1.712	1.717	1.722	1.727	1.732	1.737
2.3	1.742	1.747	1.752	1.757	1.762	1.767	1.772	1.777	1.782	1.787
2.4	1.792	1.797	1.802	1.807	1.812	1.817	1.822	1.827	1.832	1.837
2.5	1.842	1.847	1.852	1.857	1.862	1.867	1.871	1.876	1.881	1.886
2.6	1.891	1.896	1.900	1.905	1.910	1.915	1.920	1.925	1.929	1.934
2.7	1.939	1.944	1.949	1.953	1.958	1.963	1.968	1.972	1.977	1.982
2.8	1.987	1.992	1.996	2.001	2.006	2.010	2.015	2.020	2.024	2.020
2.9	2.034	2.038	2.043	2.048	2.052	2.057	2.062	2.066	2.071	2.075
3.0	2.080	2.085	2.089	2.094	2.099	2.103	2.108	2.112	2.117	2.122
3.1	2.126	2.131	2.135	2.140	2.144	2.149	2.153	2.158	2.163	2.167
3.2	2.172	2.176	2.180	2.185	2.190	2.194	2.199	2.203	2.208	2.212
3.3	2.217	2.221	2.226	2.230	2.234	2.239	2.243	2.248	2.252	2.257
3.4	2.261	2.265	2.270	2.274	2.279	2.283	2.288	2.292	2.296	2.301
3.5	2.305	2.310	2.314	2.318	2.323	2.327	2.331	2.336	2.340	2.345
3.6	2.349	2.353	2.358	2.362	2.366	2.371	2.375	2.379	2.384	2.388
3.7	2.392	2.397	2.401	2.405	2.409	2.414	2.418	2.422	2.427	2.431
3.8	2.435	2.439	2.444	2.448	2.452	2.457	2.461	2.465	2.469	2.474
3.9	2.478	2.482	2.486	2.490	2.495	2.499	2.503	2.507	2.511	2.516
4.0	2.520	2.524	2.528	2.532	2.537	2.541	2.545	2.549	2.553	2.558
4.1	2.562	2.566	2.570	2.574	2.579	2.583	2.587	2.591	2.595	2.590
4.2	2.603	2.607	2.611	2.616	2.620	2.624	2.628	2.632	2.636	2.640
4.3	2.644	2.648	2.653	2.657	2.661	2.665	2.669	2.673	2.677	2.681
4.4	2.685	2.689	2.693	2.698	2.702	2.706	2.710	2.714	2.718	2.722
4.5	2.726	2.730	2.734	2.738	2.742	2.746	2.750	2.754	2.758	2.762
4.6	2.766	2.770	2.774	2.778	2.782	2.786	2.790	2.794	2.798	2.802
4.7	2.806	2.810	2.814	2.818	2.822	2.826	2.830	2.834	2.838	2.842
4.8	2.846	2.850	2.854	2.858	2.862	2.865	2.869	2.873	2.877	2.881
4.9	2.885	2.889	2.893	2.897	2.901	2.904	2.908	2.912	2.916	2.920

TABLE B - VALUES OF $S^{1/2}$.*

S	...-0	...-1	...-2	...-3	...-4	...-5	...-6	...-7	...-8	...-9
.00001	.003162	.003317	.003464	.003606	.003742	.003873	.004000	.004123	.004243	.004359
.00002	.004472	.004583	.004690	.004796	.004899	.005000	.005099	.005196	.005292	.005385
.00003	.005477	.005568	.005657	.005745	.005831	.005916	.006000	.006083	.006164	.006245
.00004	.006325	.006403	.006481	.006557	.006633	.006708	.006782	.006856	.006928	.007000
.00005	.007071	.007141	.007211	.007280	.007348	.007416	.007483	.007550	.007616	.007681
.00006	.007746	.007810	.007874	.007937	.008000	.008062	.008124	.008185	.008246	.008307
.00007	.008367	.008426	.008485	.008544	.008602	.008660	.008718	.008775	.008832	.008888
.00008	.008944	.009000	.009055	.009110	.009165	.009220	.009274	.009327	.009381	.009434
.00009	.009487	.009539	.009592	.009644	.009695	.009747	.009798	.009849	.009899	.009950
.00010	.010000	.010050	.010100	.010149	.010198	.010247	.010296	.010344	.010392	.010440
.0001	.01000	.01049	.01095	.01140	.01183	.01225	.01265	.01304	.01342	.01378
.0002	.01414	.01449	.01483	.01517	.01549	.01581	.01612	.01643	.01673	.01703
.0003	.01732	.01761	.01789	.01817	.01844	.01871	.01897	.01924	.01949	.01975
.0004	.02000	.02025	.02049	.02074	.02098	.02121	.02145	.02168	.02191	.02214
.0005	.02236	.02258	.02280	.02302	.02324	.02345	.02366	.02387	.02408	.02429
.0006	.02449	.02470	.02490	.02510	.02530	.02550	.02569	.02588	.02608	.02627
.0007	.02646	.02665	.02683	.02702	.02720	.02739	.02757	.02775	.02793	.02811
.0008	.02828	.02846	.02864	.02881	.02898	.02915	.02932	.02950	.02966	.02983
.0009	.03000	.03017	.03033	.03050	.03066	.03082	.03098	.03114	.03130	.03146
.0010	.03162	.03178	.03194	.03209	.03225	.03240	.03256	.03271	.03286	.03302
.001	.03162	.03317	.03464	.03606	.03742	.03873	.04000	.04123	.04243	.04359
.002	.04472	.04583	.04690	.04796	.04899	.05000	.05099	.05196	.05292	.05385
.003	.05477	.05568	.05657	.05745	.05831	.05916	.06000	.06083	.06164	.06245
.004	.06325	.06403	.06481	.06557	.06633	.06708	.06782	.06856	.06928	.07000
.005	.07071	.07141	.07211	.07280	.07348	.07416	.07483	.07550	.07616	.07681
.006	.07746	.07810	.07874	.07937	.08000	.08062	.08124	.08185	.08246	.08307
.007	.08367	.08426	.08485	.08544	.08602	.08660	.08718	.08775	.08832	.08888
.008	.08944	.09000	.09055	.09110	.09165	.09220	.09274	.09327	.09381	.09434
.009	.09487	.09539	.09592	.09644	.09695	.09747	.09798	.09849	.09899	.09950
.010	.10000	.10050	.10100	.10149	.10198	.10247	.10296	.10344	.10392	.10440
.01	.1000	.1049	.1095	.1140	.1183	.1225	.1265	.1304	.1342	.1378
.02	.1414	.1449	.1483	.1517	.1549	.1581	.1612	.1643	.1673	.1703
.03	.1732	.1761	.1789	.1817	.1844	.1871	.1897	.1924	.1949	.1975
.04	.2000	.2025	.2049	.2074	.2098	.2121	.2145	.2168	.2191	.2214
.05	.2236	.2258	.2280	.2302	.2324	.2345	.2366	.2387	.2408	.2429
.06	.2449	.2470	.2490	.2510	.2530	.2550	.2569	.2588	.2608	.2627
07	.2646	.2665	.2683	.2702	.2720	.2739	.2757	.2775	.2793	.2811
08	.2828	.2846	.2864	.2881	.2898	.2915	.2933	.2950	.2966	.2983
.09	.3000	.3017	.3033	.3050	.3066	.3082	.3098	.3114	.3130	.3146
.10	.3162	.3178	.3194	.3209	.3225	.3240	.3256	.3271	.3286	.3302

* From King, Handbook of Hydraulics, McGraw-Hill.

DRAINAGE & SEWERAGE

SCOBEY CHART FOR THE SOLUTION OF KUTTER'S FORMULA

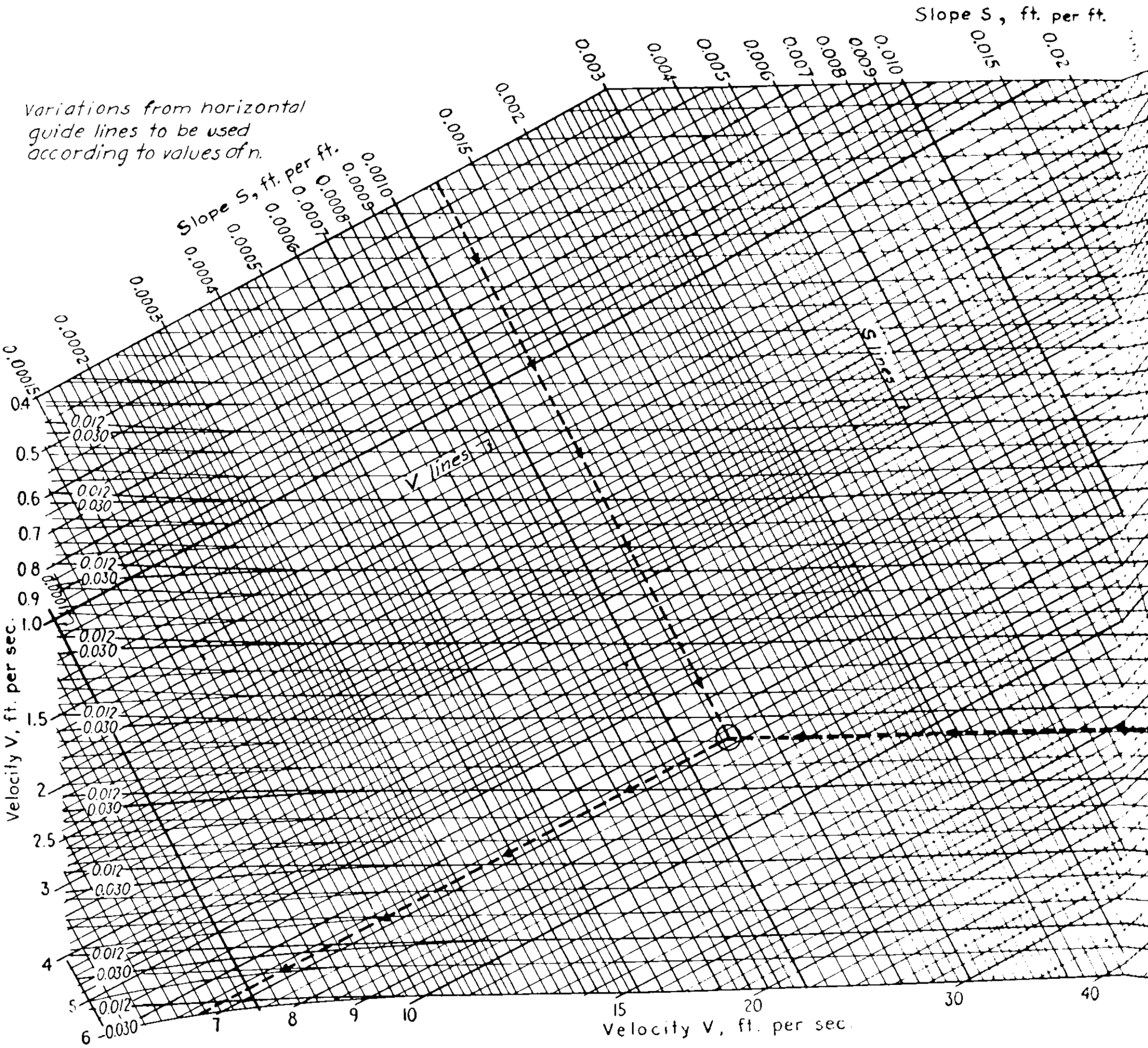
KUTTER'S FORMULA

$Q = ac\sqrt{RS}$ in which

$$C = \frac{41.65 + \frac{0.00281}{S} + \frac{1.811}{n}}{1 + \left(41.65 + \frac{0.00281}{S}\right)\frac{n}{\sqrt{R}}}$$

EXAMPLE:

Given: A concrete lined channel,—
a(cross sectional area) = 60 sq. ft.
R(hydraulic radius = $\frac{\text{area}}{\text{wetted perimeter}}$) = 2.6 ft.
n(coefficient of roughness - see Table. A, page 5-26) = 0.0
S(longitudinal slope) = 0.00124 ft. per ft.



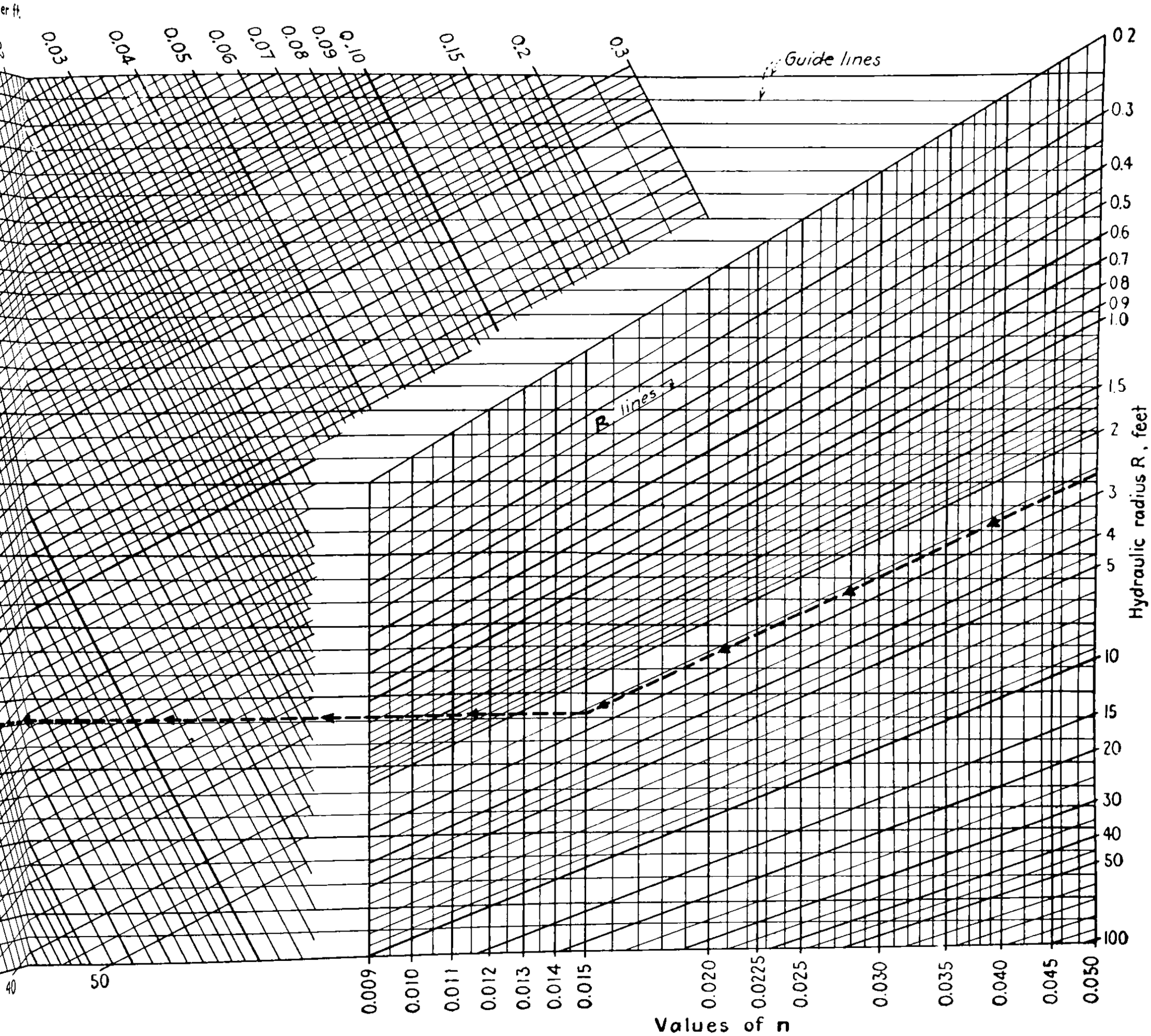
For permission to reproduce this diagram the author is indebted to the Division of Irrigation, Soil Conserva
printed in Creager and Justin's "Hydroelectric Handbook", 1927.

HYDRAULIC COMPUTATION-3

RMULA FOR FLOW IN OPEN CHANNELS.*

REQUIRED: *To find V (velocity in ft. per sec.) and Q (discharge in c.f.s.)*
Enter chart at R = 2.6; proceed parallel with oblique R lines to intersection with n = 0.015; thence horizontally to intersection with S = 0.00124; thence parallel with oblique V line to V scale; read V = 6.75 ft. per sec.
∴ Q = aV = 60 × 6.75 = 405 c.f.s.

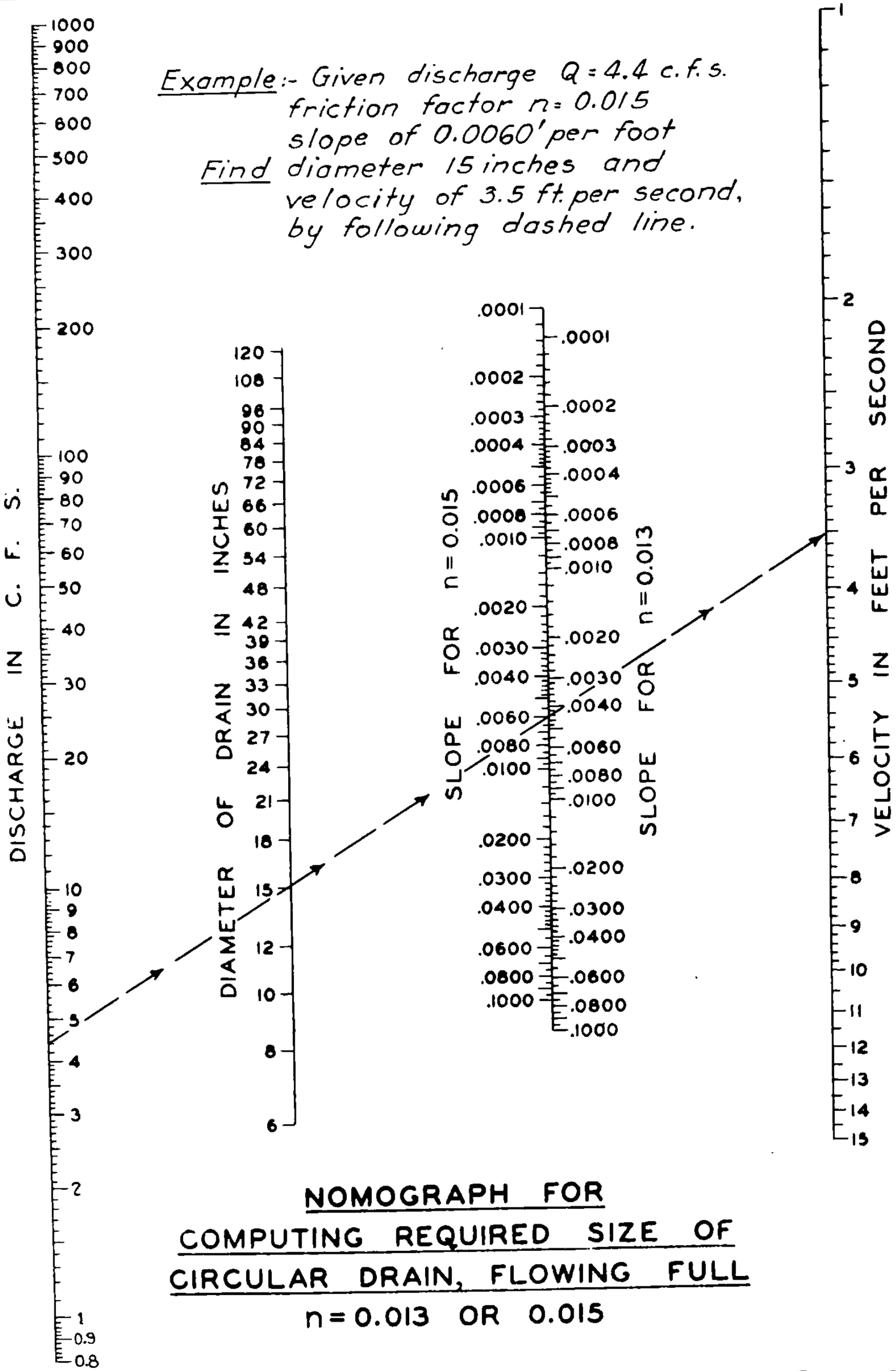
) = 0.015



Conservation Service, U.S. Department of Agriculture and to Mr. Scobey. In this form it was first

DRAINAGE & SEWERAGE - HYDRAULIC COMPUTATION-4

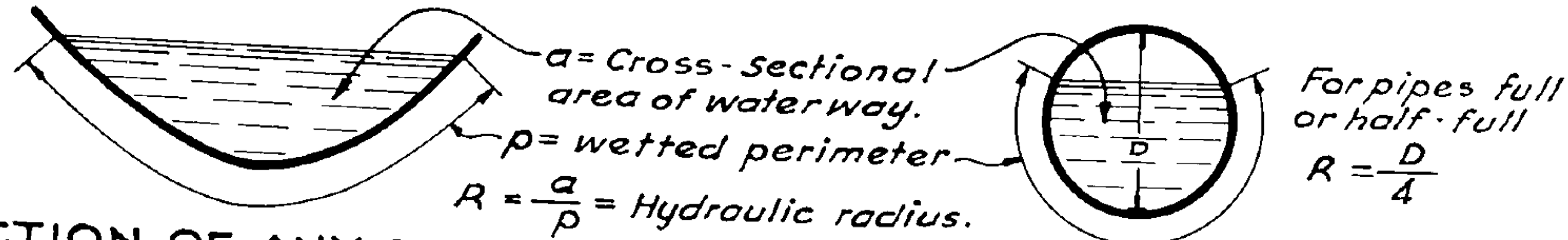
Example:- Given discharge Q = 4.4 c.f.s.
friction factor n = 0.015
slope of 0.0060' per foot
Find diameter 15 inches and
velocity of 3.5 ft. per second,
by following dashed line.



NOMOGRAPH FOR
COMPUTING REQUIRED SIZE OF
CIRCULAR DRAIN, FLOWING FULL
n = 0.013 OR 0.015

Adapted from Engineering Manual, War Department, Corps of Engineers, Sept. 1942.

DRAINAGE & SEWERAGE – HYDRAULIC COMPUTATION-5



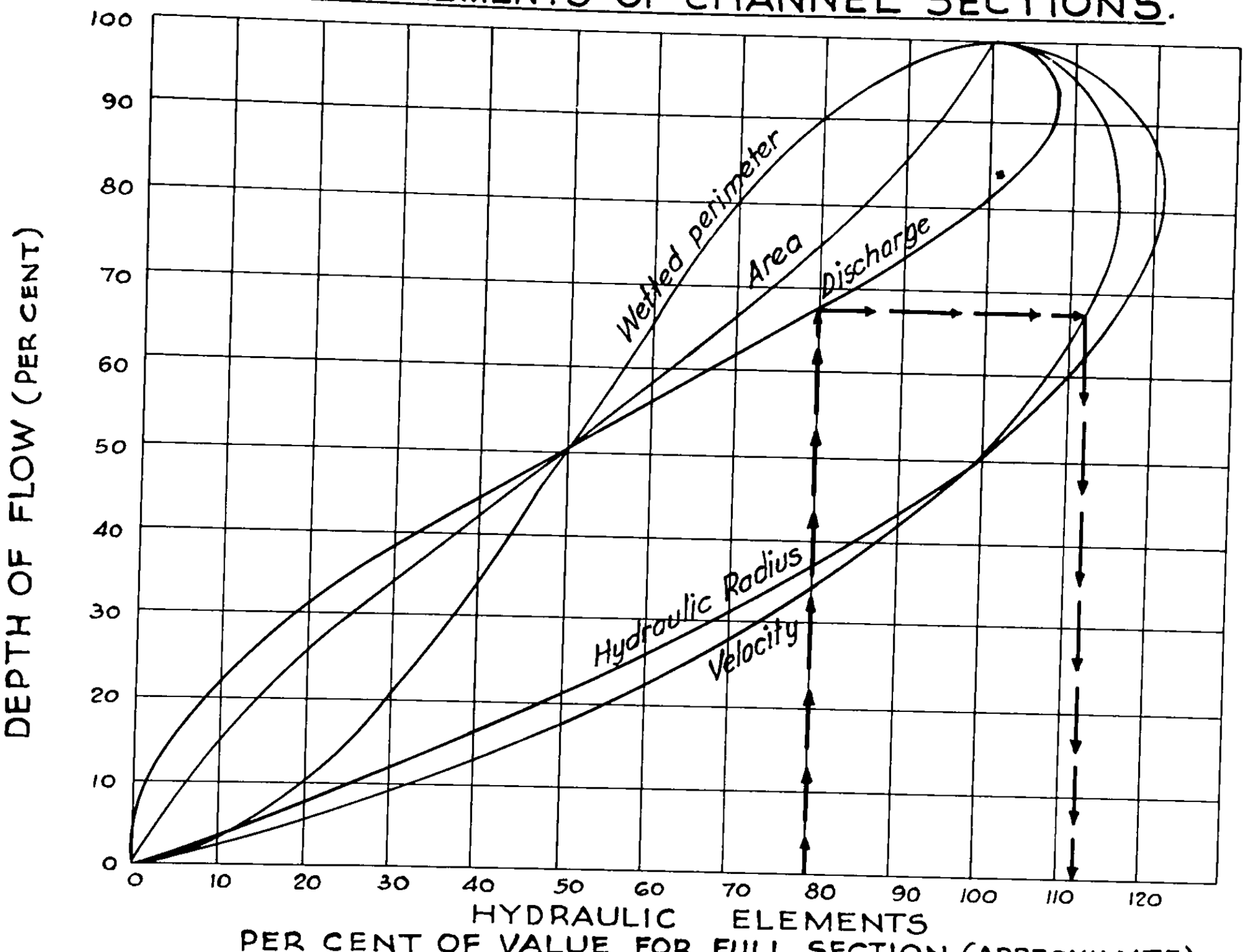
$R = \frac{a}{p}$ = Hydraulic radius.

SECTION OF ANY CHANNEL

SECTION OF CIRCULAR PIPE

V = Average or mean velocity in feet per second.
$Q = aV$ = Discharge of pipe or channel in cubic feet per second (c.f.s.).
n = Coefficient of roughness of pipe or channel surface, see Table A-Pg. 5-26.
S = Slope of Hydraulic Gradient (water surface in open channels or pipes not under pressure, same as slope of channel or pipe invert only when flow is uniform in constant section.

FIG. A- HYDRAULIC ELEMENTS OF CHANNEL SECTIONS.

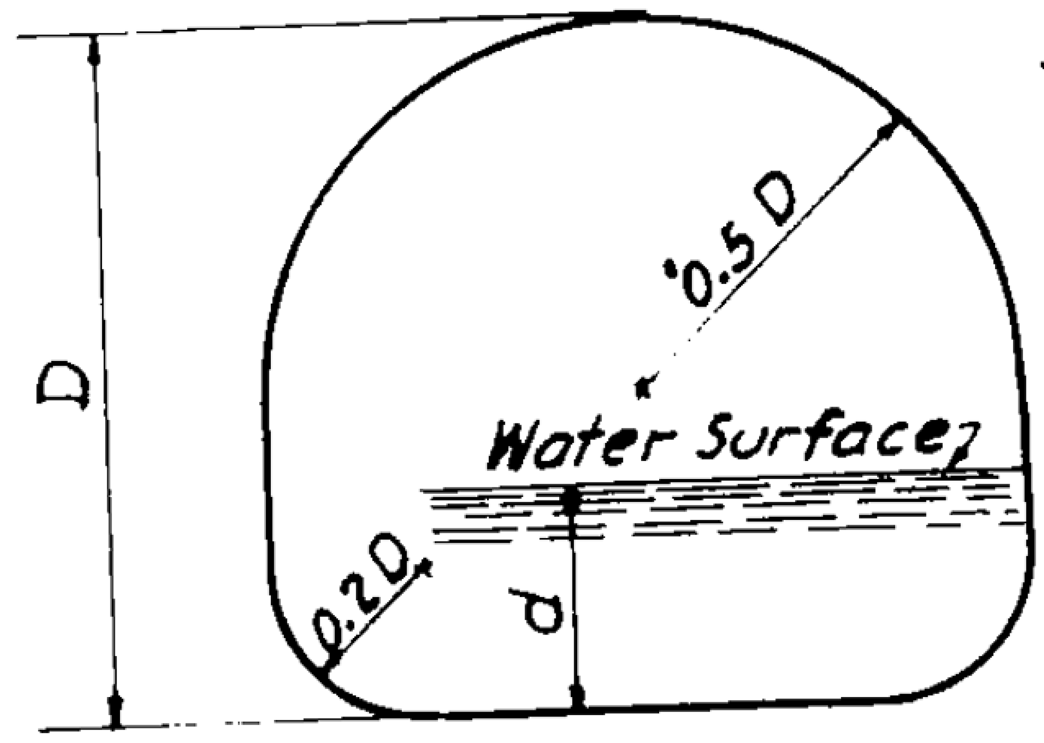


EXAMPLE: Given: Discharge = 12 c.f.s. through a pipe which has capacity flowing full of 15 c.f.s. at a velocity of 7.0 ft. per sec. Required to find V for Q = 12 c.f.s. ∴ Percentage of full discharge = $\frac{12}{15}$ = 80%. Enter chart at 80% of value for full section of Hydraulic Elements, find V = 112.5%×7 = 7.9 ft. per sec.

FIG. B-VALUES OF HYDRAULIC ELEMENTS OF CIRCULAR SECTION FOR VARIOUS DEPTHS OF FLOW.

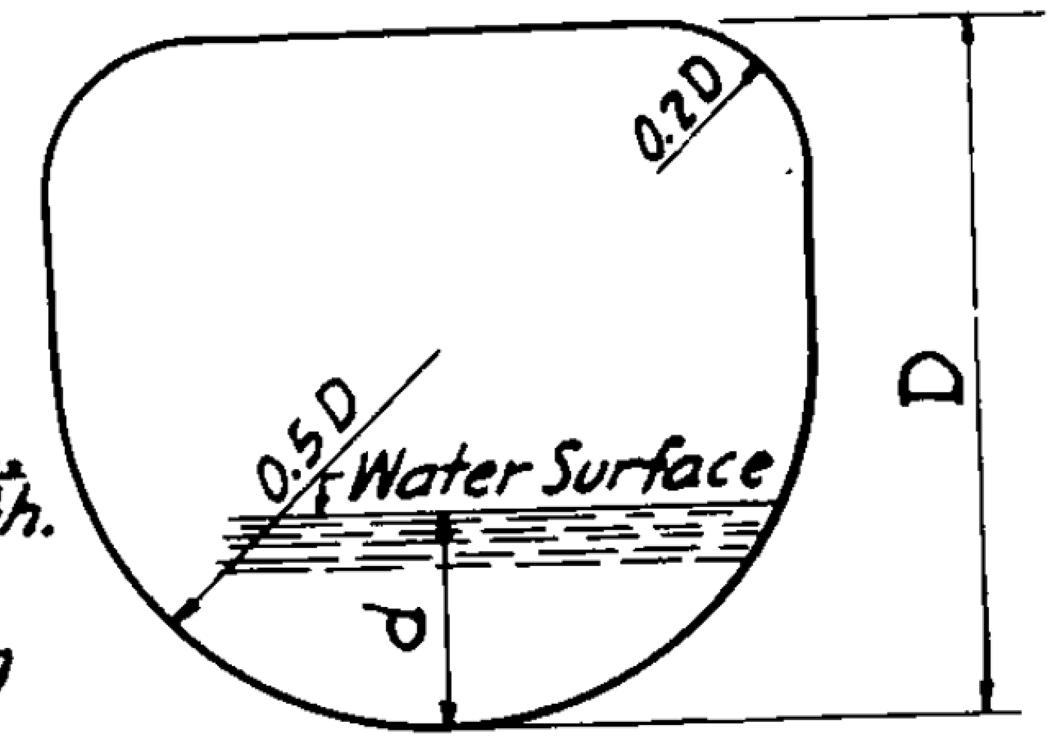
DRAINAGE & SEWERAGE - HYDRAULIC COMPUTATION-6

HYDRAULIC ELEMENTS OF MASSEY FLAT BASE PIPE.*



FULL PIPE.
Area = A = .876 D^2
Hyd. Rad. = R = .258D
Velocity = V
Wetted Perim. = P
Discharge = Q

PARTIALLY FILLED PIPE.
Small letters are for "d" depth.
Diameter of Circle with equal carrying Capacity = 1.05D



$\frac{d}{D}$	FLAT BASE PIPE UPRIGHT.					FLAT BASE PIPE INVERTED.				
	$\frac{a}{A}$	$\frac{p}{P}$	$\frac{r}{R}$	$\frac{v}{V}$	$\frac{q}{Q}$	$\frac{a}{A}$	$\frac{p}{P}$	$\frac{r}{R}$	$\frac{v}{V}$	$\frac{q}{Q}$
0	0	0	0	0	0	0	0	0	0	0
0.05	0.043	0.261	0.167	0.301	0.013	0.017	0.132	0.124	0.247	0.004
0.10	0.096	0.300	0.322	0.469	0.045	0.047	0.190	0.248	0.395	0.018
0.15	0.152	0.331	0.457	0.595	0.090	0.084	0.234	0.360	0.506	0.043
0.20	0.209	0.361	0.577	0.694	0.144	0.127	0.272	0.469	0.605	0.077
0.25	0.266	0.391	0.678	0.773	0.205	0.175	0.308	0.566	0.684	0.119
0.30	0.323	0.420	0.767	0.840	0.271	0.226	0.341	0.663	0.760	0.172
0.35	0.380	0.450	0.845	0.894	0.339	0.278	0.372	0.748	0.825	0.230
0.40	0.437	0.479	0.911	0.941	0.411	0.334	0.403	0.829	0.884	0.296
0.45	0.494	0.508	0.973	0.983	0.484	0.390	0.433	0.903	0.936	0.365
0.50	0.551	0.538	1.023	1.017	0.561	0.447	0.462	0.969	0.978	0.437
0.55	0.609	0.567	1.074	1.049	0.639	0.504	0.491	1.023	1.017	0.513
0.60	0.665	0.597	1.116	1.077	0.716	0.562	0.521	1.077	1.052	0.590
0.65	0.721	0.628	1.151	1.099	0.792	0.619	0.550	1.124	1.081	0.670
0.70	0.774	0.659	1.174	1.114	0.862	0.676	0.580	1.163	1.106	0.746
0.75	0.825	0.692	1.194	1.126	0.930	0.733	0.609	1.202	1.131	0.831
0.80	0.873	0.727	1.198	1.128	0.986	0.790	0.639	1.233	1.151	0.907
0.85	0.916	0.766	1.194	1.126	1.031	0.848	0.669	1.267	1.173	0.994
0.90	0.953	0.810	1.178	1.116	1.062	0.904	0.700	1.291	1.185	1.070
0.95	0.983	0.868	1.132	1.086	1.068	0.957	0.739	1.295	1.188	1.135
1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

EXAMPLES: Use Manning Formula - $V = \frac{1.486}{n} r^{2/3} s^{1/2}$ (see Pg. 5-27).

Given: D = 80" or 6.67' S = 0.0016 n = 0.012
$A = 0.876 \times 6.67^2 = 38.90$ Sq. Ft.
$R = 0.258 \times 6.67 = 1.72$
V = 7.12 Ft. per Sec.
Q = 277 Cu. Ft. per Sec.

Find q when flowing 2 feet deep = 0.3 D

(a) Upright Section: $r = 0.767 \times 1.72 = 1.32$ V = 5.95 Ft. per Sec.
$a = 0.323 \times 38.90 = 12.57$ $q = av = 5.95 \times 12.57 = 74.9$ c.f.s.
(From Table) $v = 0.84 \times 7.12 = 5.98$ Ft. per Sec. $q = .271 \times 277 = 75.0$ c.f.s.

(b) Inverted Section: $r = 0.663 \times 1.72 = 1.14$ v = 5.40 Ft. per Sec.
$a = 0.226 \times 38.90 = 8.85$ $q = 8.85 \times 5.40 = 47.8$ c.f.s.
(From Table) $v = 0.76 \times 7.12 = 5.40$ Ft. per Sec. $q = .172 \times 277 = 47.6$ c.f.s.

* From Massey Concrete Products Company.

DRAINAGE & SEWERAGE-MINOR LOSSES-INVERTED SIPHONS

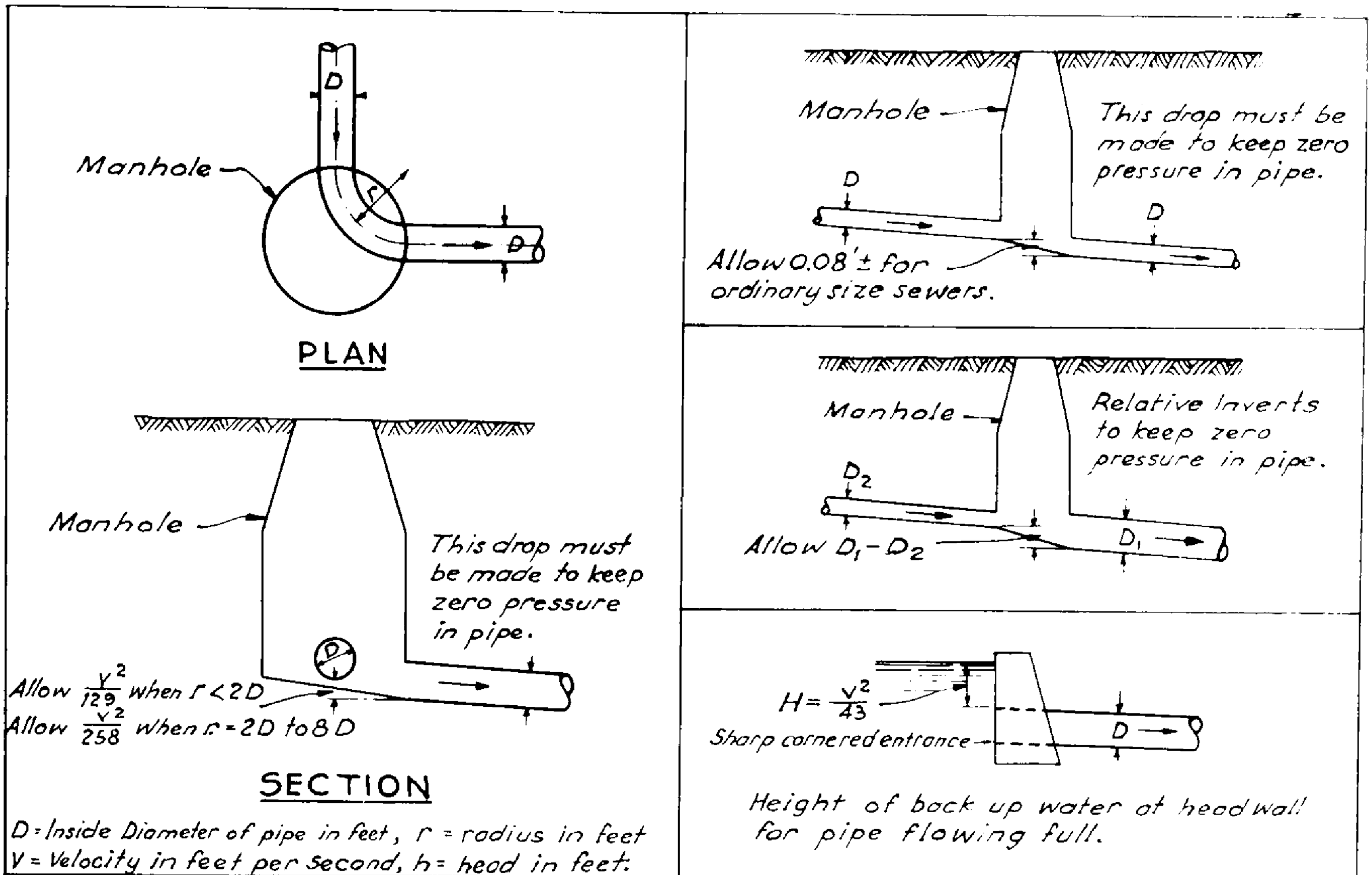


FIG. A— SPECIAL HEAD LOSS ALLOWANCES IN SEWERS.*

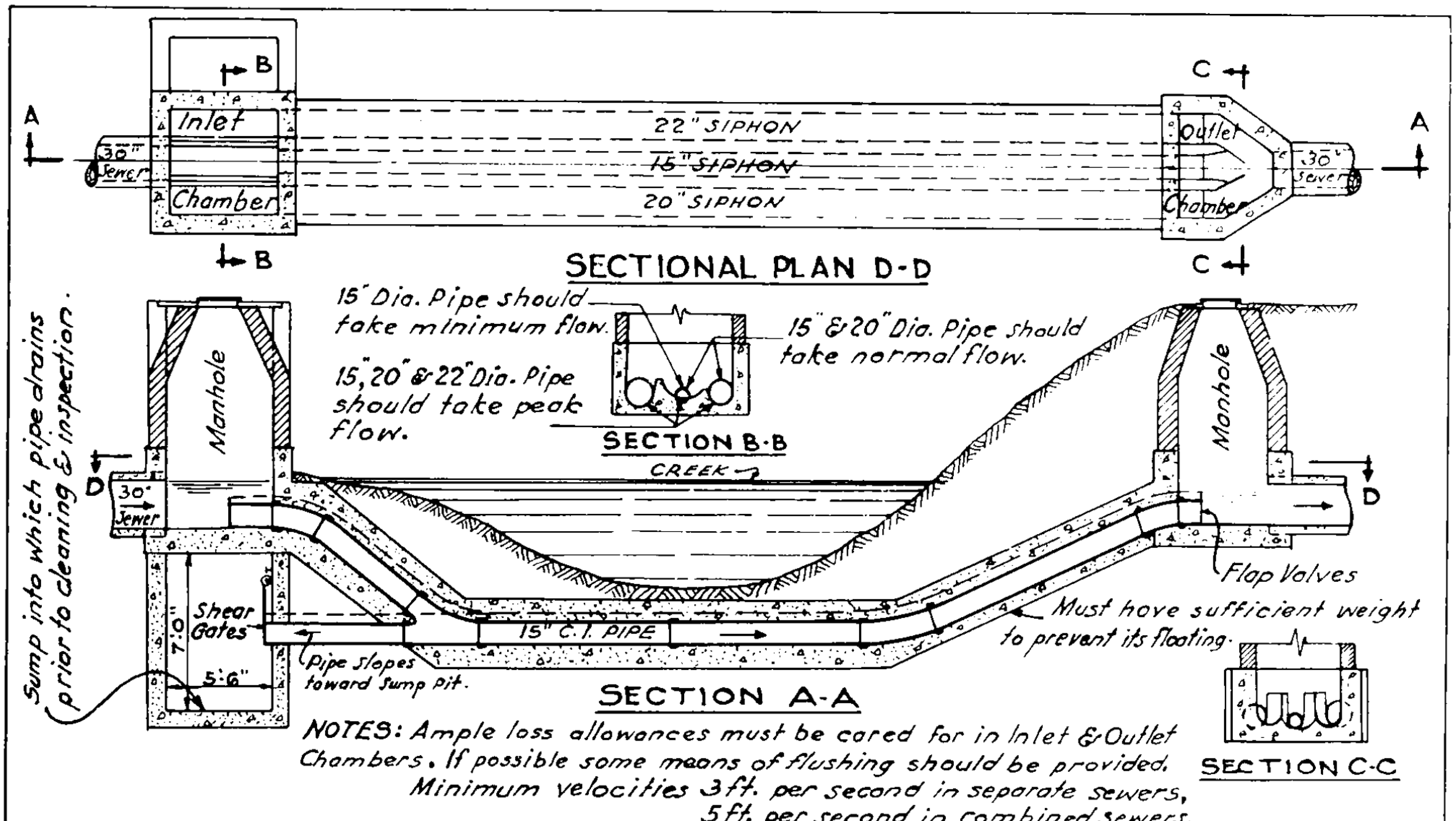
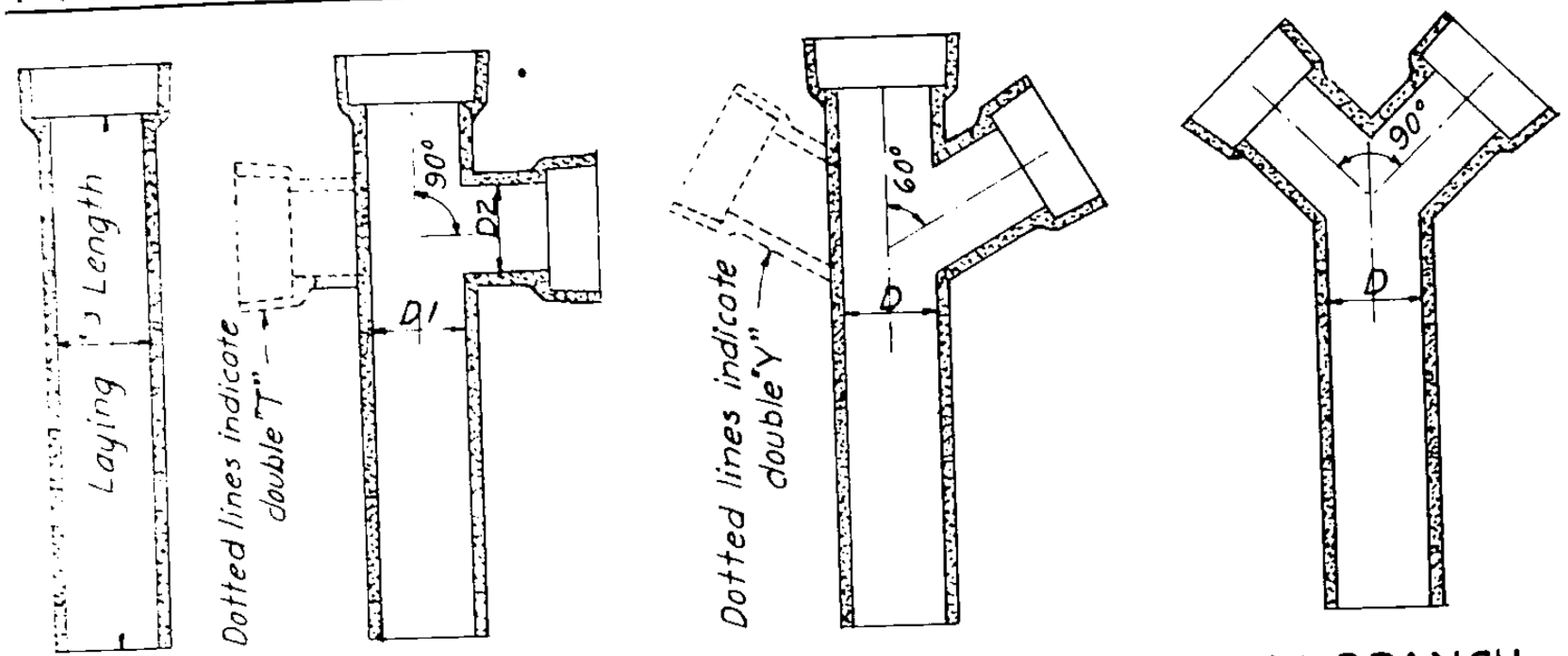


FIG. B— DETAILS OF INVERTED SIPHON.

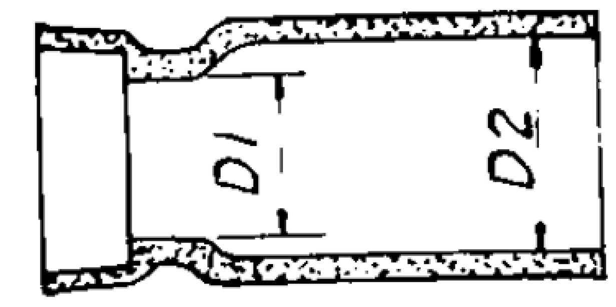
*Adapted from Davis, Handbook of Applied Hydraulics, McGraw-Hill.

DRAINAGE & SEWERAGE-PIPE DETAILS-1

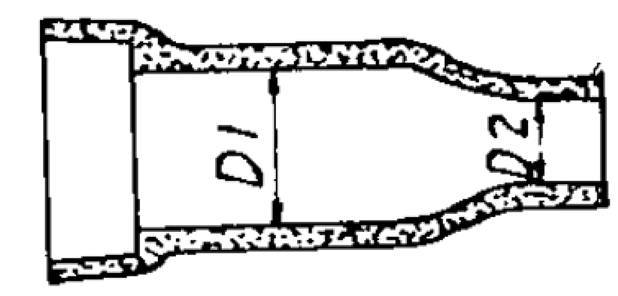
FIG. A-VITRIFIED CLAY PIPE FITTINGS, JOINTS & CONNECTIONS.



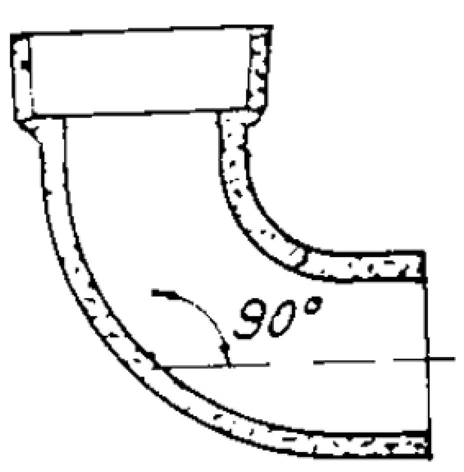
PIPE T-BRANCH Y-BRANCH V-BRANCH



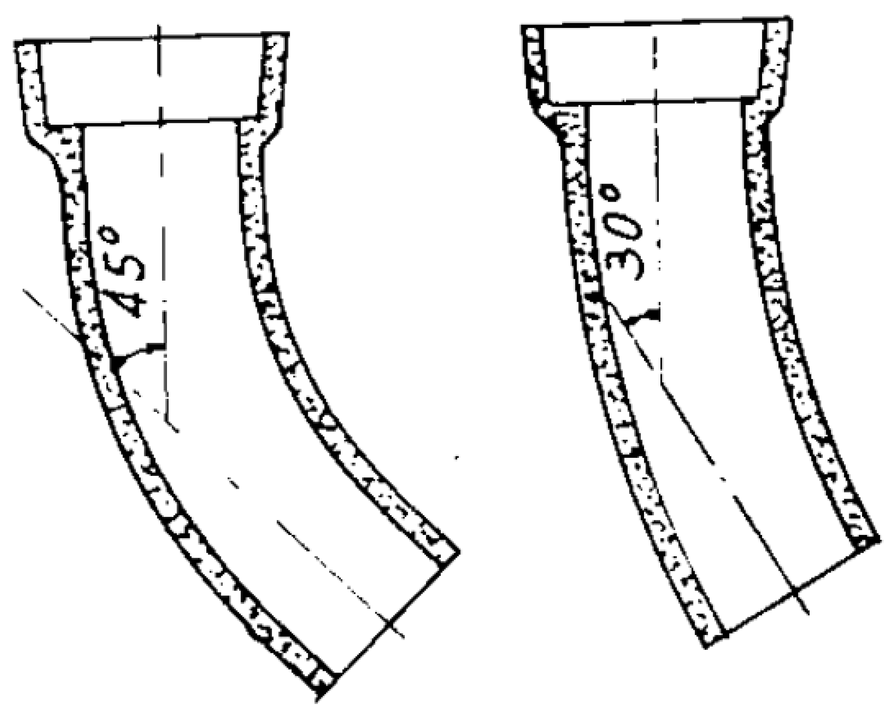
INCREASER.



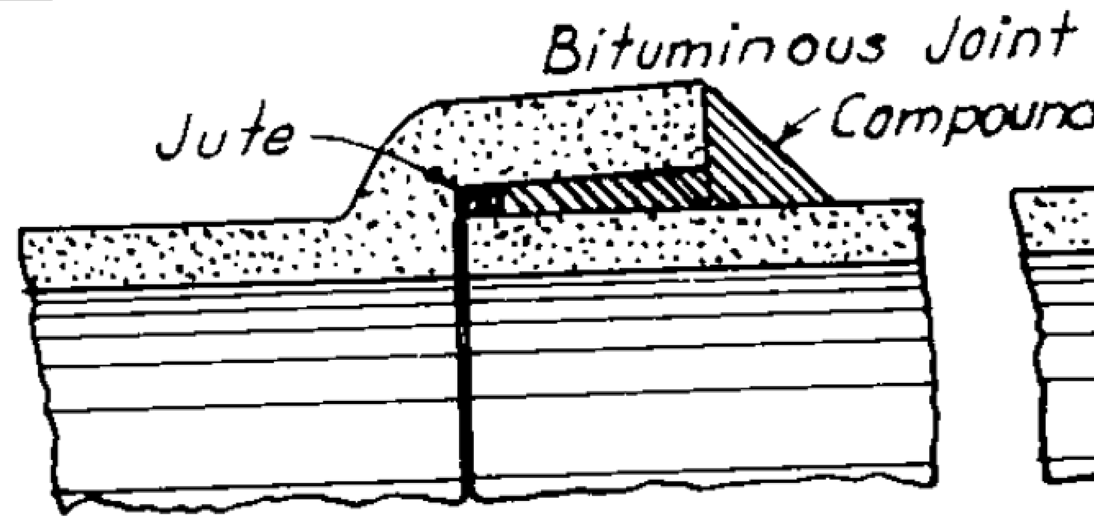
REDUCER.



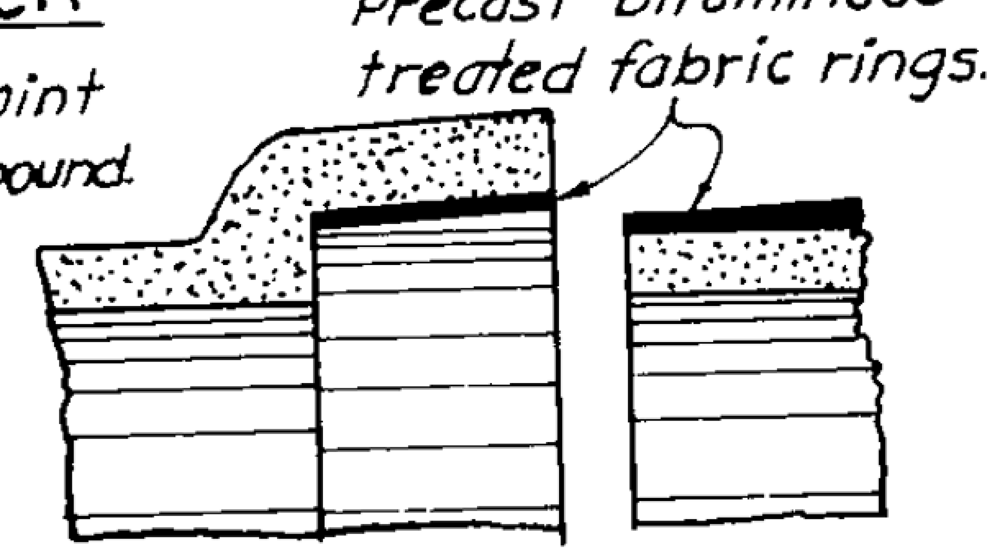
ELBOW



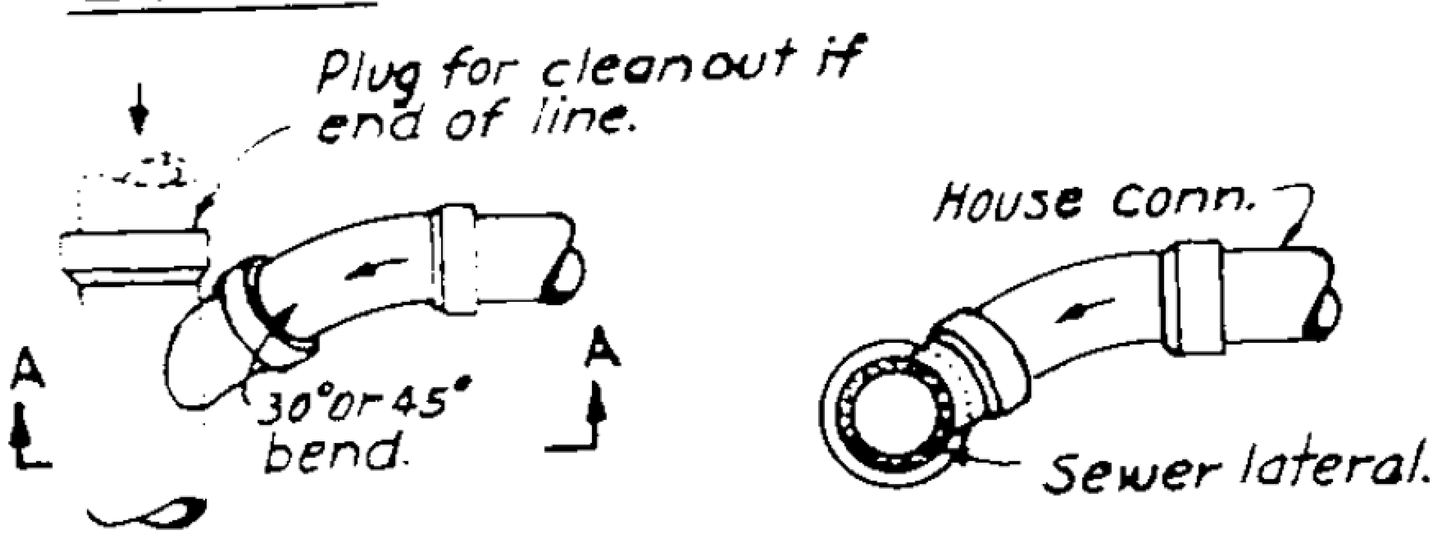
CURVE BENDS



POURED BITUMINOUS COMPOUND JOINT.



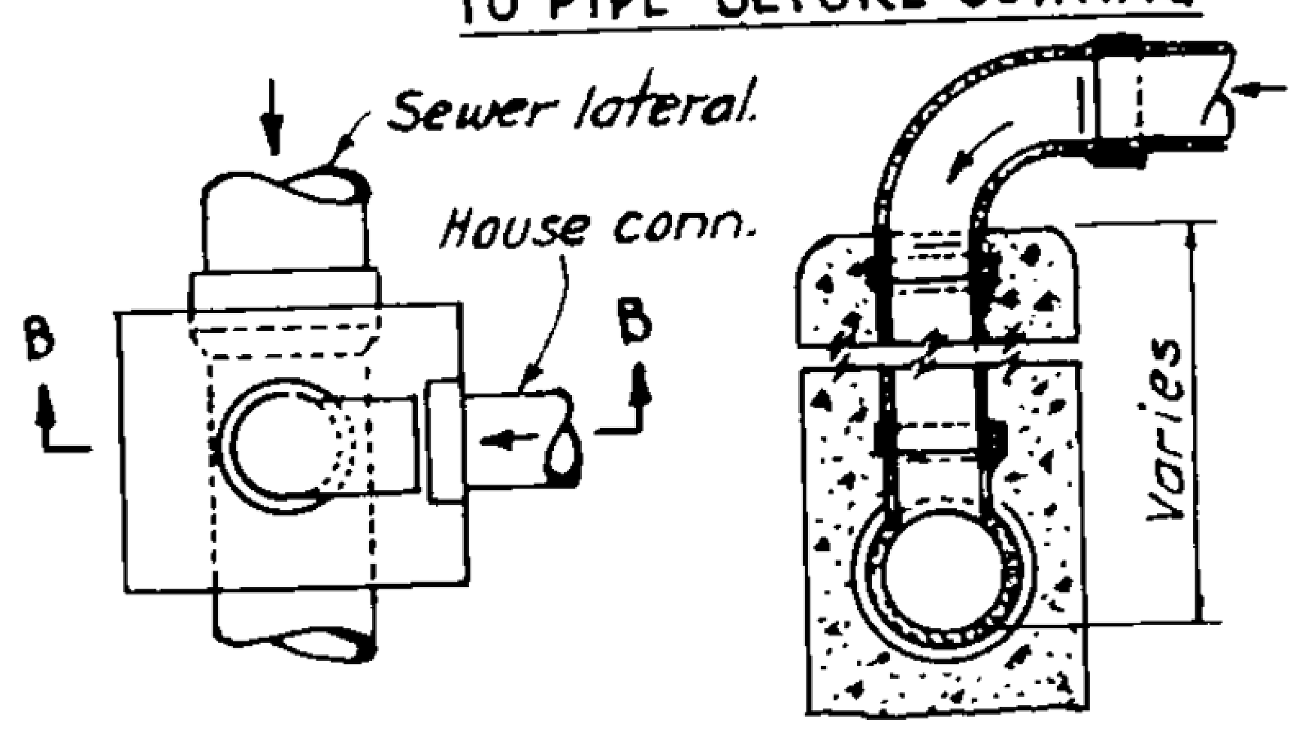
SLIP SEAL JOINT APPLIED TO PIPE BEFORE JOINING.



PLAN SECTION A-A

STANDARD SEWER HOUSE CONNECTION.

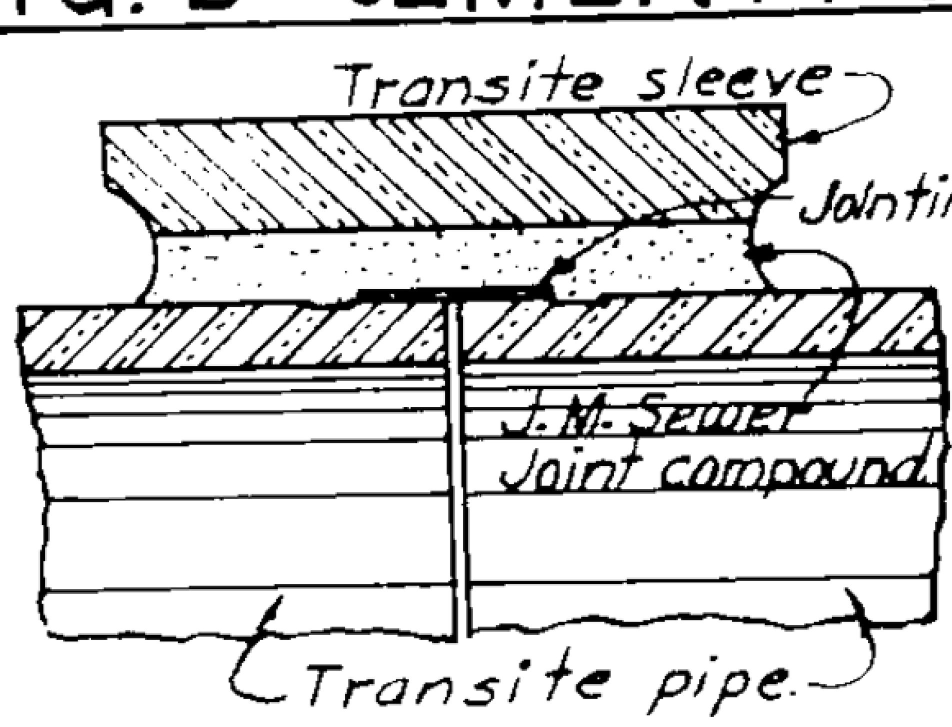
NOTE:- Sewer connections to be made at manholes if possible. Invert of house connection to be at elevation of top of lateral.

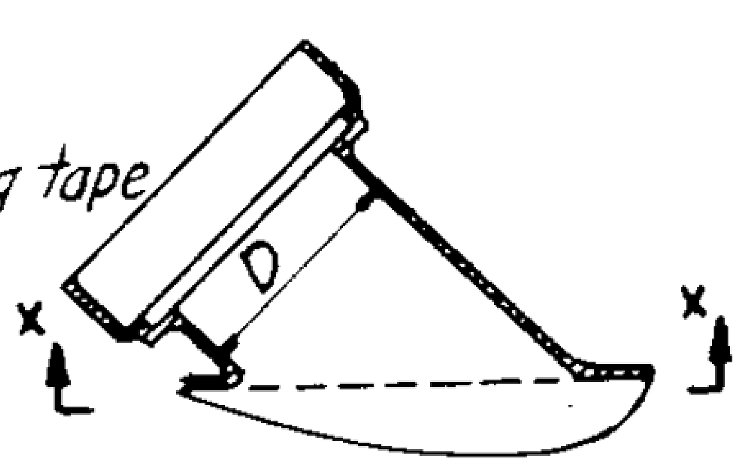


PLAN SECTION B-B

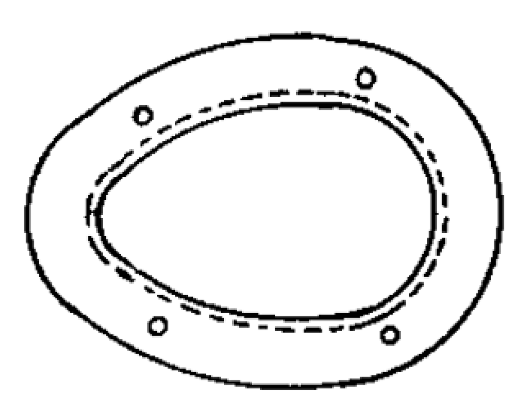
SEWER HOUSE CONNECTION WITH VERTICAL RISER.

FIG. B-CEMENT-ASBESTOS (TRANSITE) SEWER PIPE DETAILS*

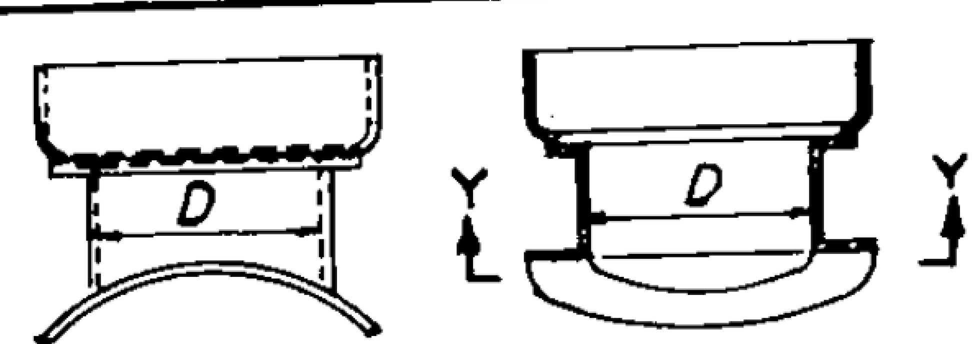




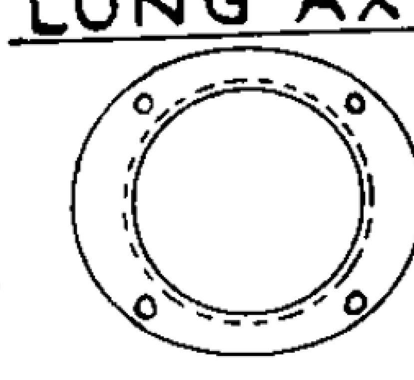
SECTION ON LONG AXIS



VIEW X-X



SECTION ON LONG AXIS.



VIEW Y-Y

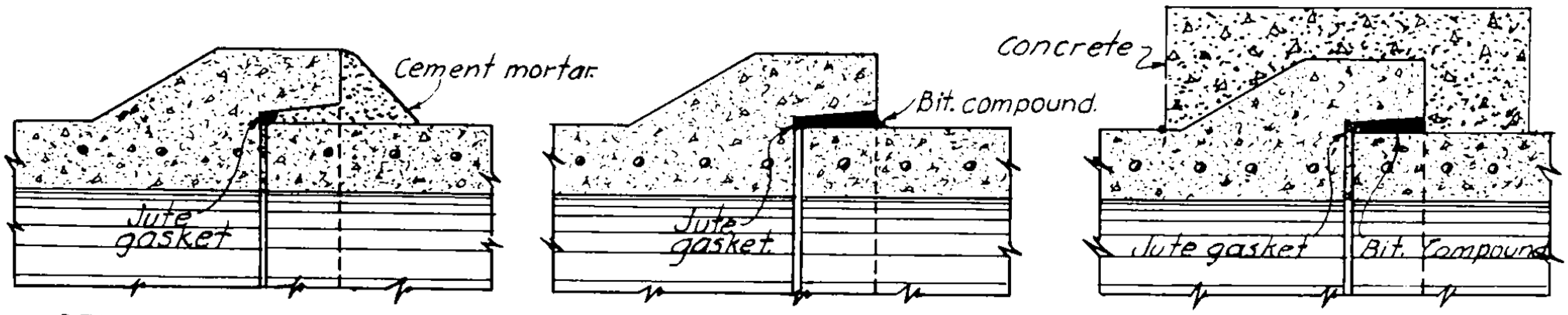
NOTE: 4 bolt holes equally spaced, bolts to be 3/8" diameter Monel carriage bolts fitted with lead washers and Monel hex. nuts. 4 supplied with each branch connection.

45 DEGREE TYPE 90 DEGREE TYPE.

CAST IRON CUT-INS FOR HOUSE CONNECTIONS TO TRANSITE PIPE

*Data from Johns-Manville Corp.

DRAINAGE & SEWERAGE - PIPE DETAILS - 2

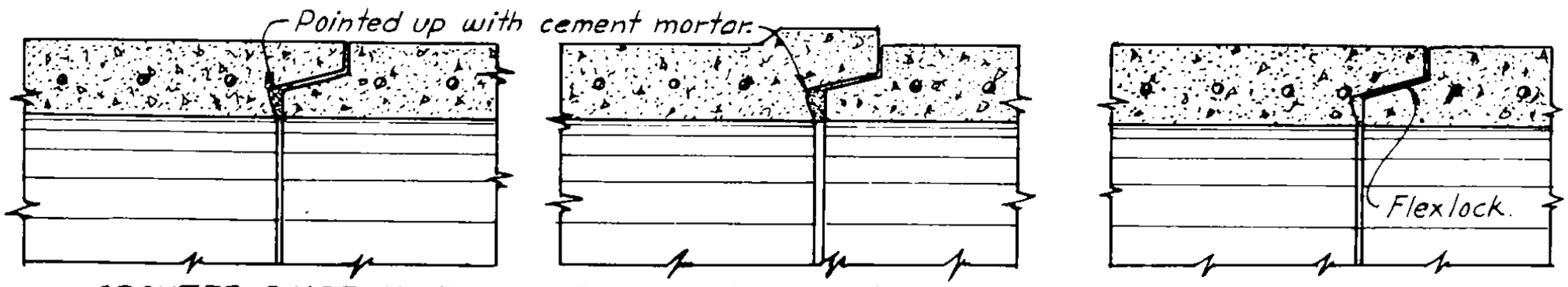


CEMENT MORTAR JOINT.

POURED BITUMINOUS COMPOUND JOINT.

CONCRETE COLLAR FOR USE IN SIPHONS OR LOW HEADS.

BELL AND SPIGOT PIPE.



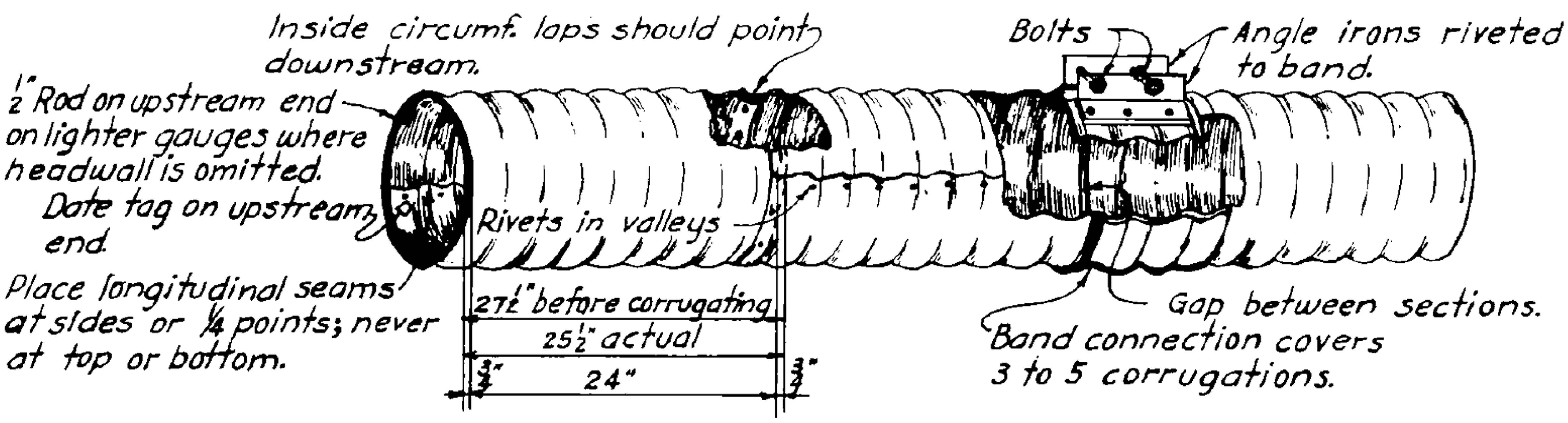
GROUTED SCARF JOINT

GROUTED IMPROVED SCARF JOINT

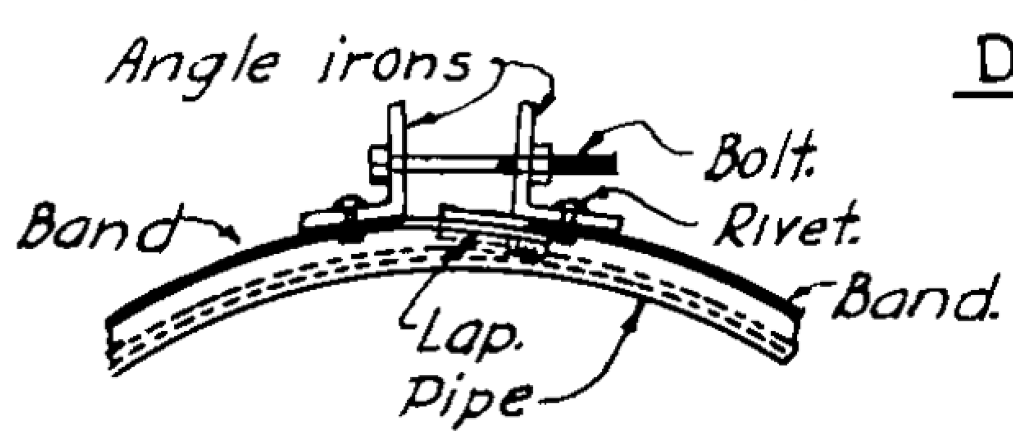
FLEXLOCK RUBBER GASKET JOINT.

SCARF JOINT PIPE.

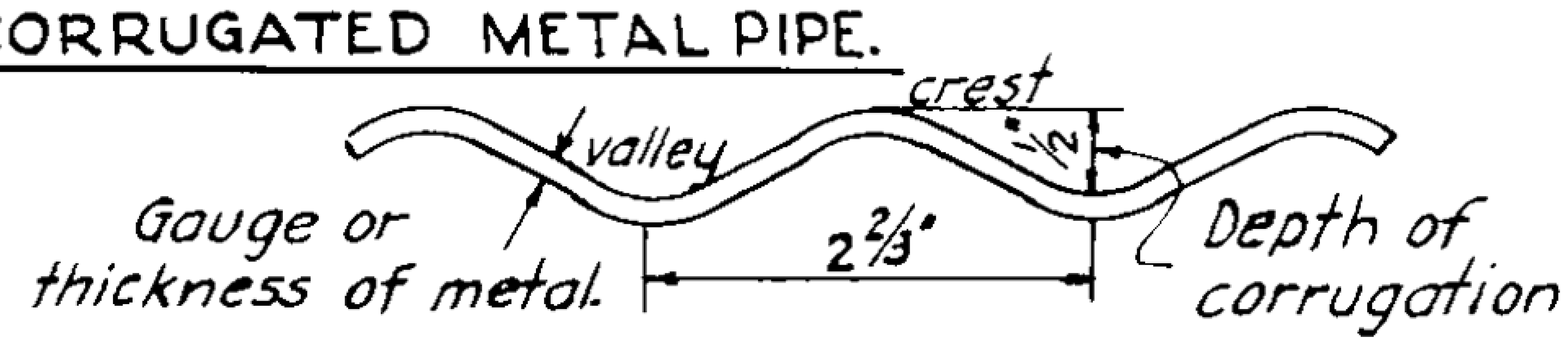
FIG. A— CONCRETE PIPE JOINTS.



DETAILS OF CORRUGATED METAL PIPE.

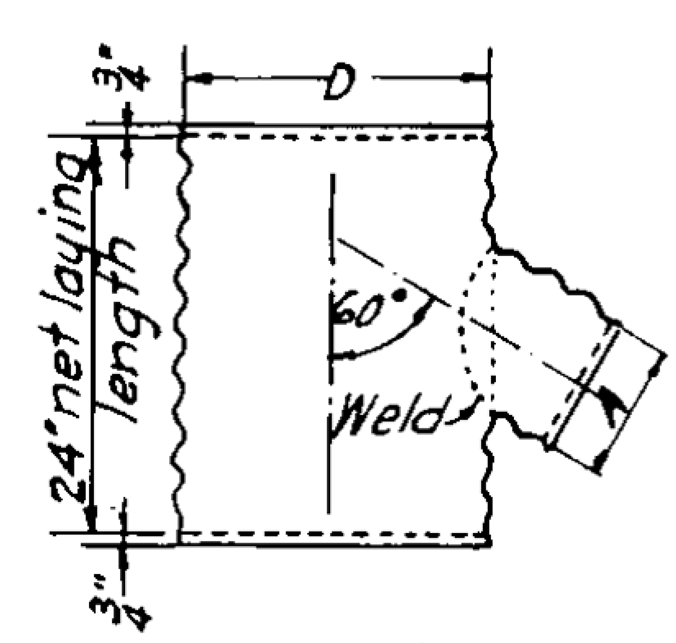


SECTION THROUGH BAND CONNECTION.

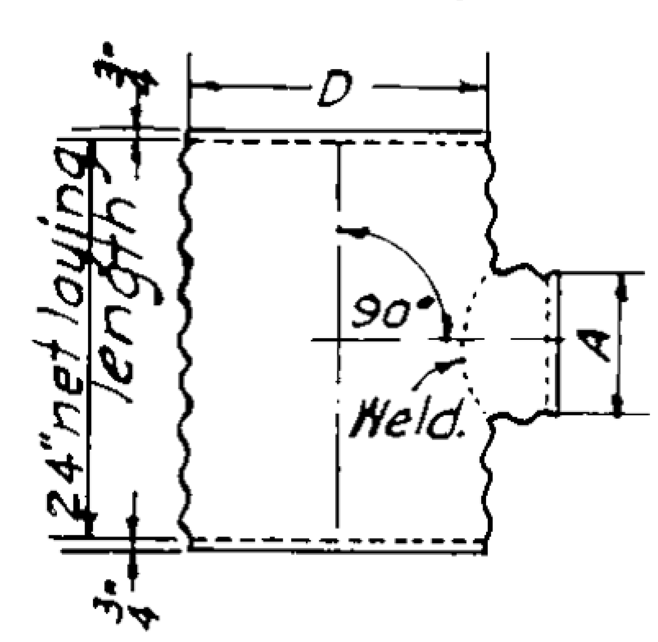


DETAILS OF CORRUGATION.

PIPE MATERIAL: Base metal is pure iron or iron copper alloy galvanized both sides.
PAVED INVERT PIPE: Has bituminous pavement filling valleys of corrugations in bottom of pipe and pipe is partly or fully bituminous coated.



Y-BRANCHES



T-BRANCHES.

FIG. B— CORRUGATED METAL PIPE DETAILS.*

* Data from Armco Drainage Products Assoc.

SEWAGE TREATMENT — GENERAL DATA

TABLE A — SEWAGE CHARACTERISTICS.*

SUSPENDED SOLIDS (S.S.)	POUNDS PER CAPITA DAILY.
1. Separate Sewers	.17
2. Combined Sewers	.33
FIVE-DAY BIOCHEMICAL OXYGEN DEMAND. (B.O.D.)	**POUNDS PER CAPITA DAILY.**
1. Residential areas only, separate sewers	.12
2. Residential areas, includ. ordinary commercial establ., separate sewers	.17
3. Residential areas, includ. ordinary commercial establ., combined sewers	.25
4. Mfg. city with no large industrial wastes	.33
5. Industrial wastes (frequently quite high)	.33 - .50 and over

TABLE B — INDUSTRIAL SEWAGE.**

APPROX. VALUES PER EMPLOYEE AS COMPARED WITH DOMESTIC SEWAGE = 1

INDUSTRY	B.O.D.	S.S.
Tannery	25.3	12.0
Chemical Manufacturing	22.5	7.4
Organic Waste	2.9	2.4
Mill Pickling	3.6	3.8
Dye Waste	44.2	5.4
Laundry	22.8	22.2
Distillery	470.0	181.0
Dairy	44.6	5.7
Miscellaneous	13.2	6.8

TABLE C — APPROX. EFFICIENCIES OF UNITS AND PLANTS.**

UNITS	SUSPENDED SOLIDS REDUCTION %	B.O.D. REDUCTION %	B. COLI (COLIFORM) REDUCTION %
Settling Tank 2 Hours	45-60	30-45	40-60
Imhoff Tank 2-3 Hours	45-60	20-45	40-60
Trickling Filter (Standard)	10-30	55-75	60-70
PLANTS			
Sedimentation Tanks (or Imhoff Tank) & Sand Filter	90-98	85-92	85-95
Sedimentation Tank & Std. Low Rate Trickling Filter	75-85	70-90	80-90
Sedimentation Tank & High Rate Filter (Recirculation a., b., c. below)			
a. Single stage intermediate (One Clarifier and One Filter) [1]		50-60 †	
b. Single stage complete (Clarifier, Filter, Clarifier all in series) [1]		75-85 †	
c. Two stage complete (Clarifier, Filter, Filter, Clarifier all in series) [1]		90-95 †	
Activated Sludge process	85-95	80-95	90-96
Chemical Treatment	65-90	45-75	60-90

TABLE D — DILUTION REQUIREMENTS.**

(TO BE USED AS GUIDE ONLY. GENERALLY STATE AUTHORITIES ESTABLISH STANDARDS FOR THE VARIOUS WATERWAYS UNDER THEIR JURISDICTION.)

	PER 1000 PERSONS
Raw Sewage	3.5-6.0 Cu. ft. per Sec.
Settled Sewage	2.0-4.0 " " "
Chem. Treatment Effluent	1.5-2.5 " " "
Trickling Filter Effluent	.5-1.0 " " "
Activated Sludge Effluent	.3-.5 " " "
Sand Filter Effluent	.3-.5 " " "

TABLE E — APPROXIMATE RESULTS OBTAINABLE BY PRIMARY AND BY COMPLETE TREATMENT OF AVERAGE DOMESTIC SEWAGE.

	RAW SEWAGE	AFTER PRIMARY TREATMENT	AFTER COMPLETE TREATMENT
B.O.D.	250 P.P.M.	140-200	15-60
Suspended Solids	250 P.P.M.	100-140	15-50

[1] See page 5-42 — Flow Diagrams.

* From Davis, Handbook of Applied Hydraulics, Mc Graw-Hill

** From Principles of Sewage Treatment by Dr. Willem Rudolfs, published by National Lime Association, Washington, D.C.

† From The Dorr Co.

SEWAGE TREATMENT – FLOW DIAGRAMS-1

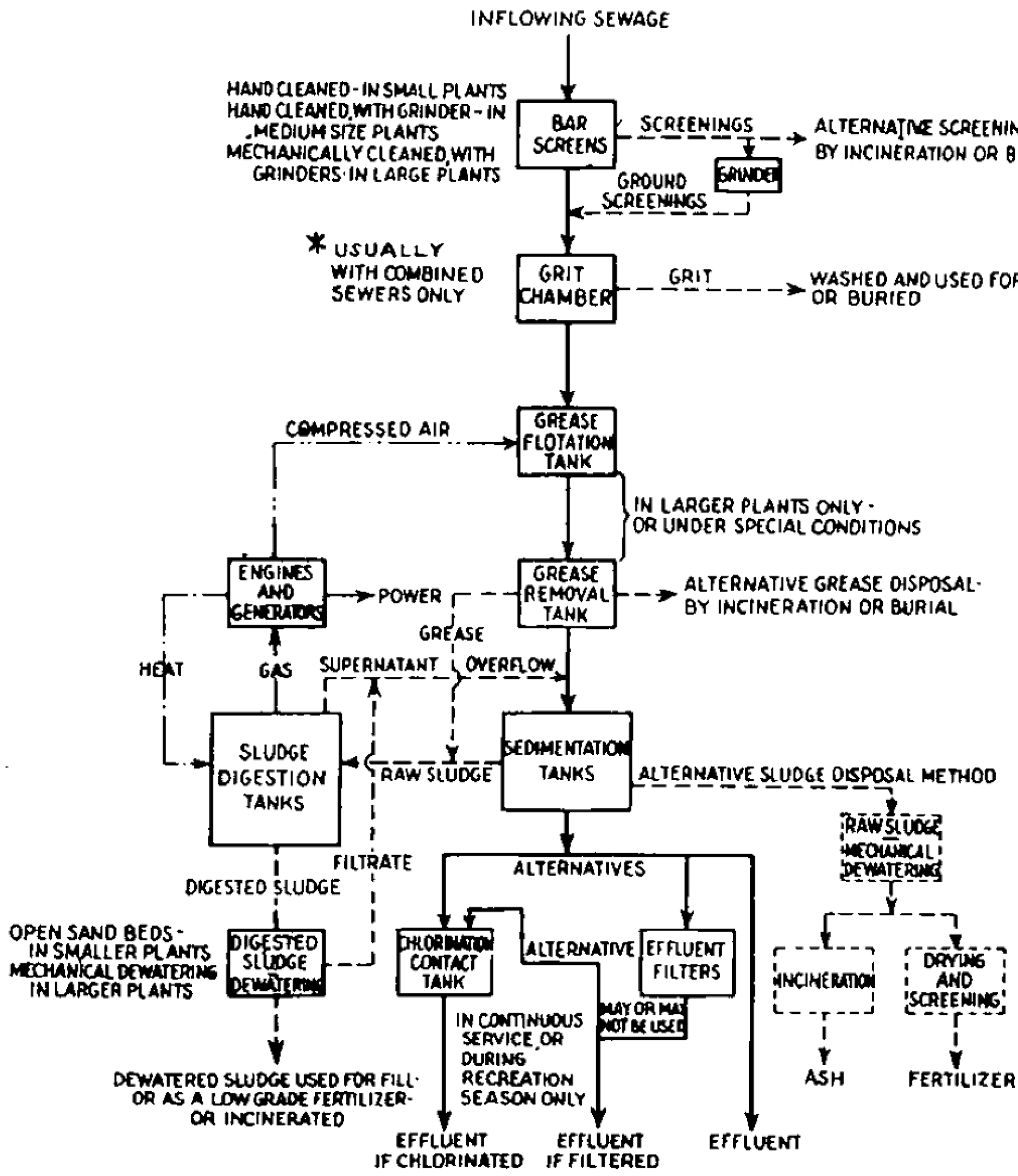


FIG. A – PLAIN SEDIMENTATION PLANT +

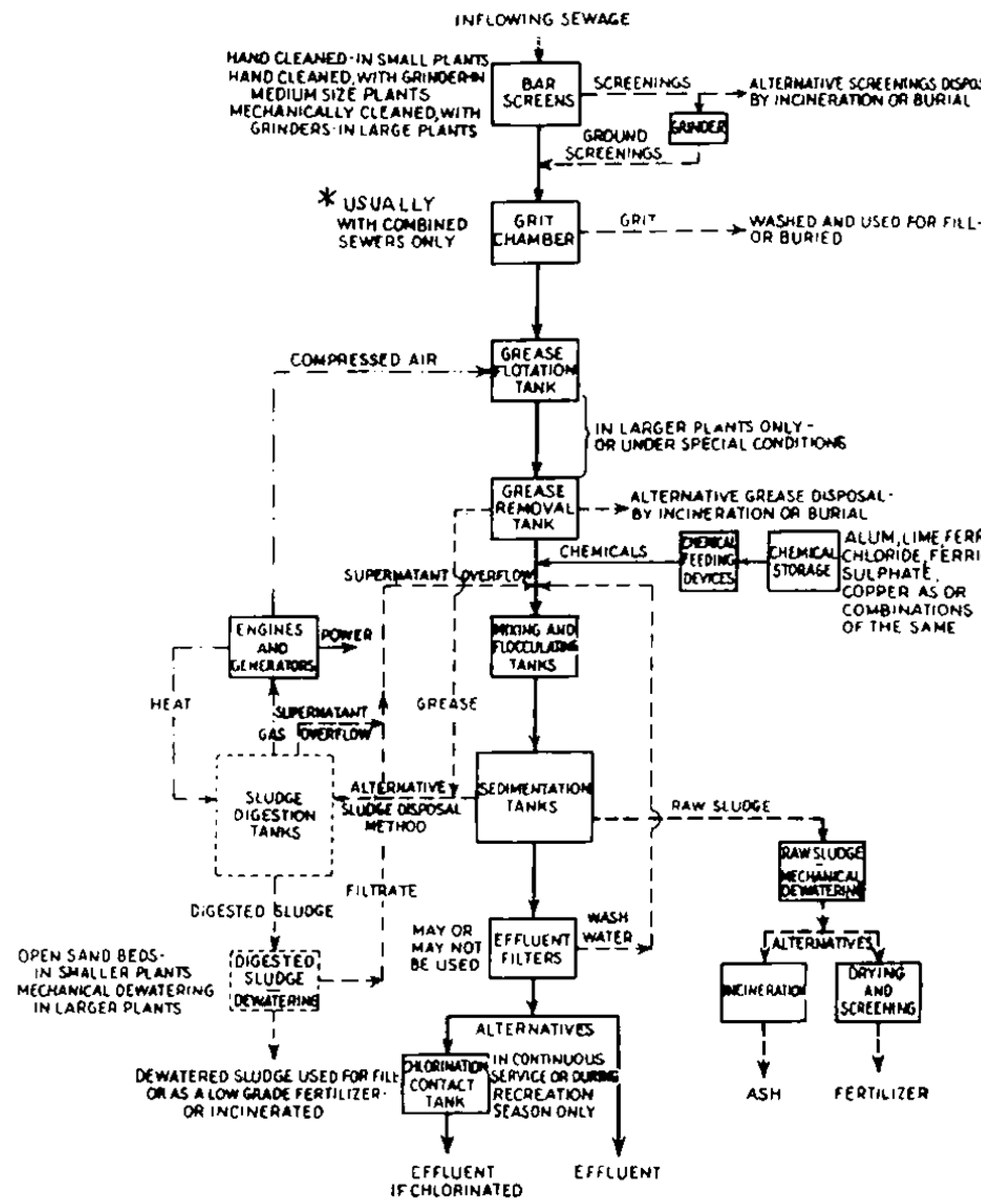


FIG. B – CHEMICAL TREATMENT PLANT.

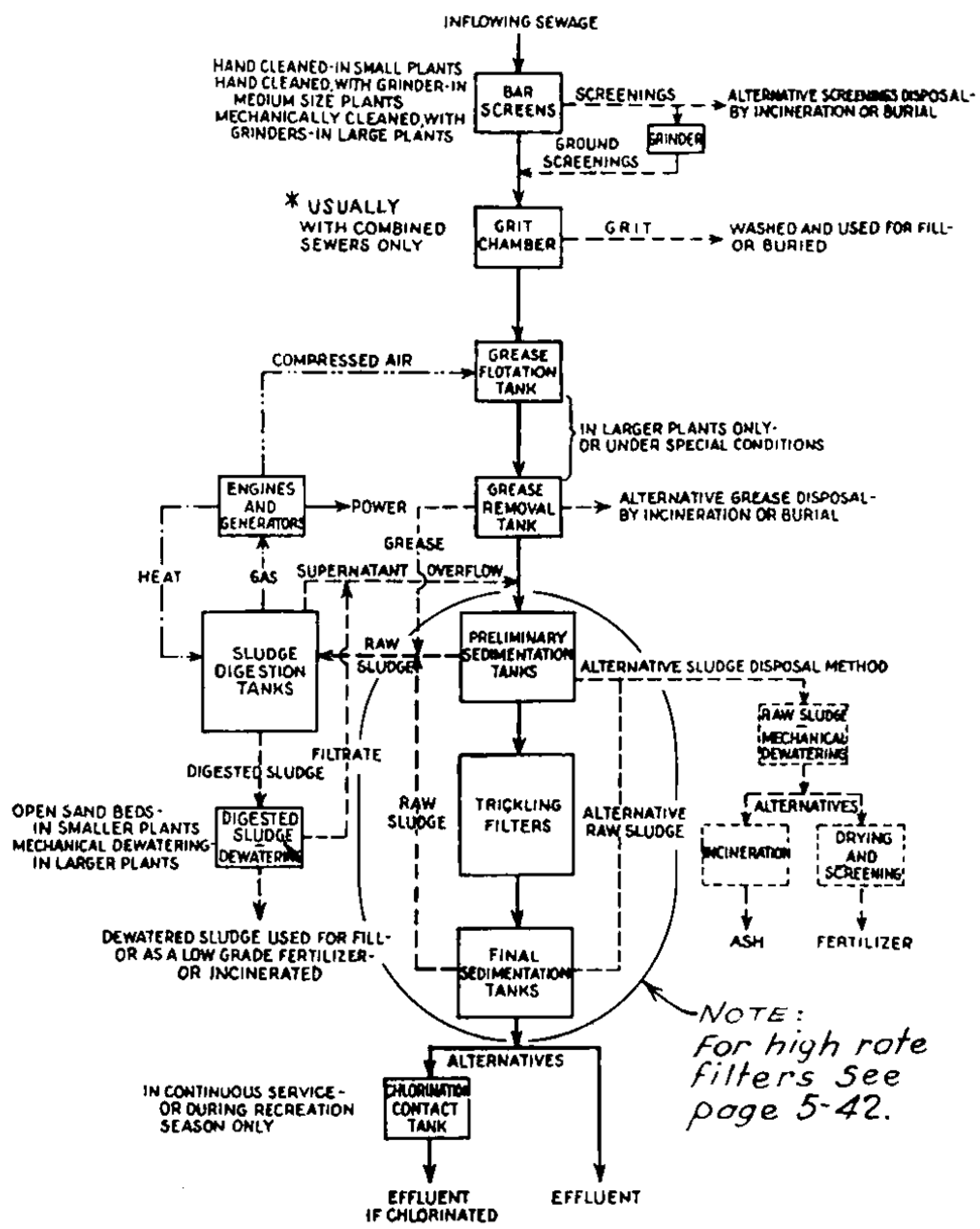


FIG. C – TRICKLING FILTER PLANT.

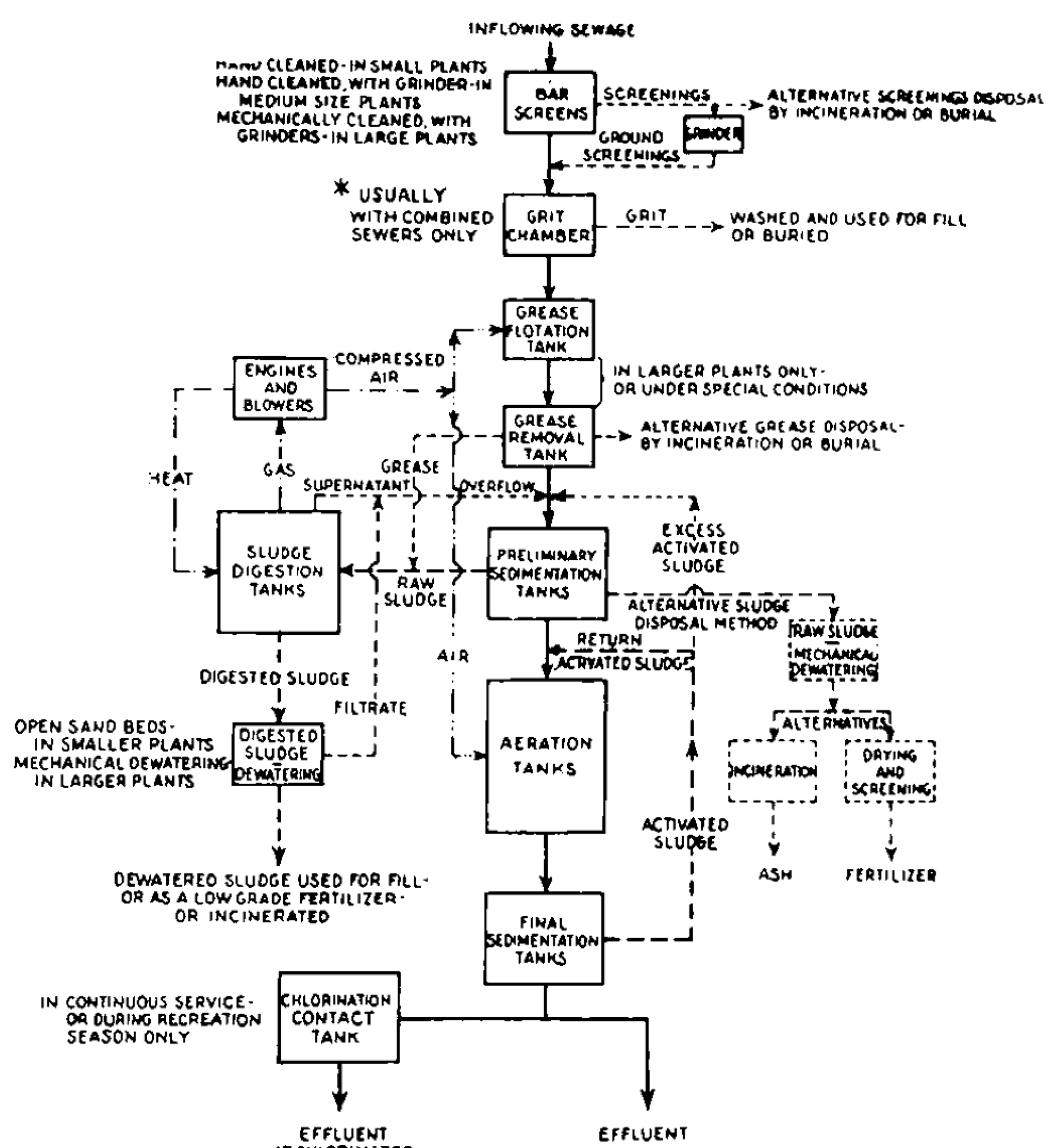
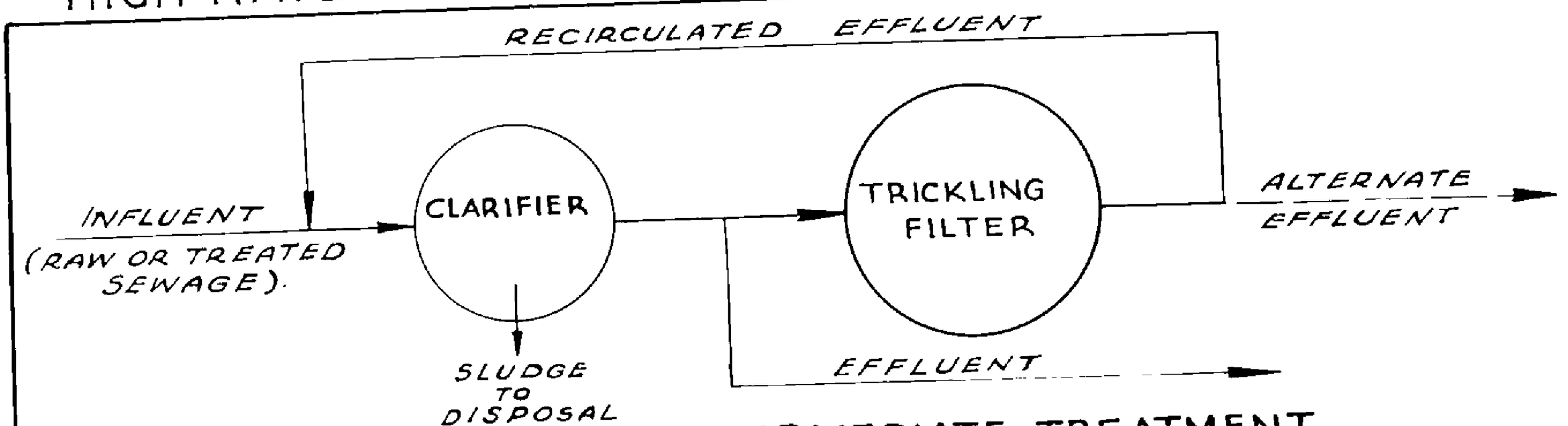


FIG. D – ACTIVATED SLUDGE PLANT.

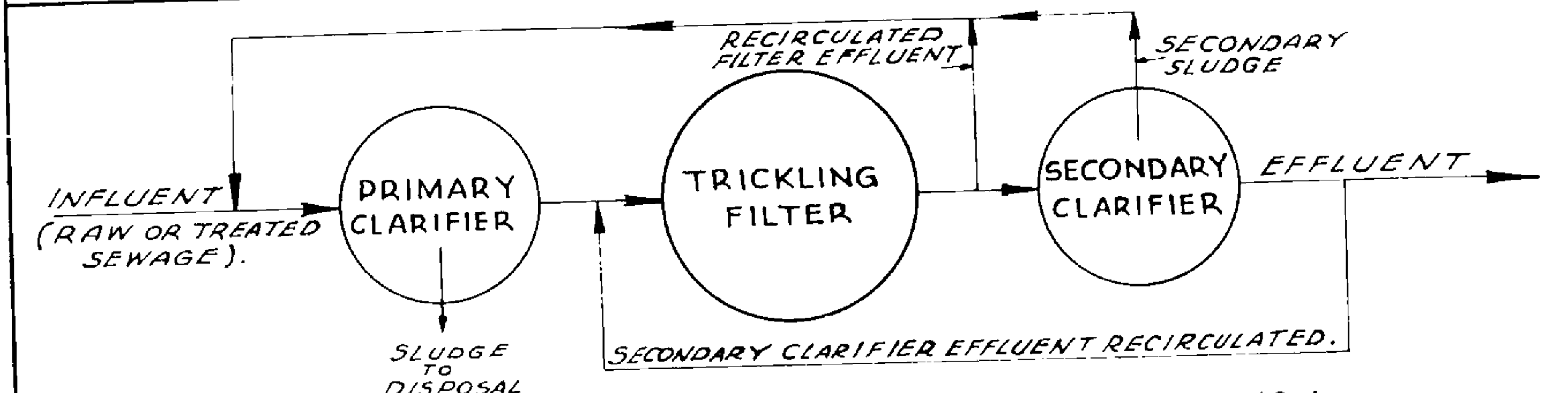
* *Large plants may require Grit Chambers.*
\+ *Including Imhoff Tanks.*
Data from Davis, Handbook of Applied Hydraulics, McGraw-Hill.

SEWAGE TREATMENT – FLOW DIAGRAMS-2

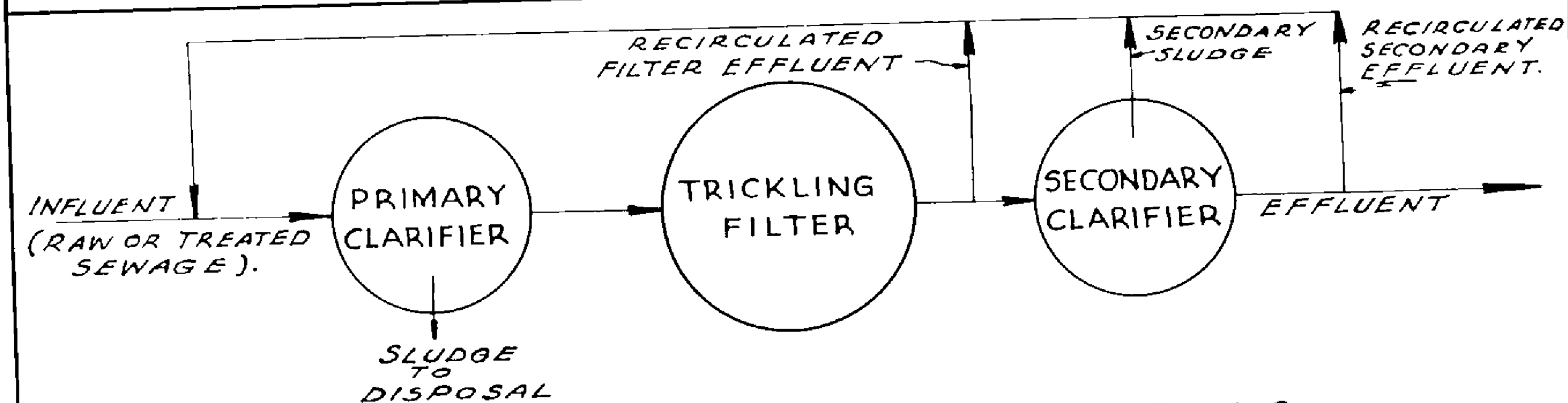
HIGH RATE TRICKLING FILTERS – RECIRCULATION.



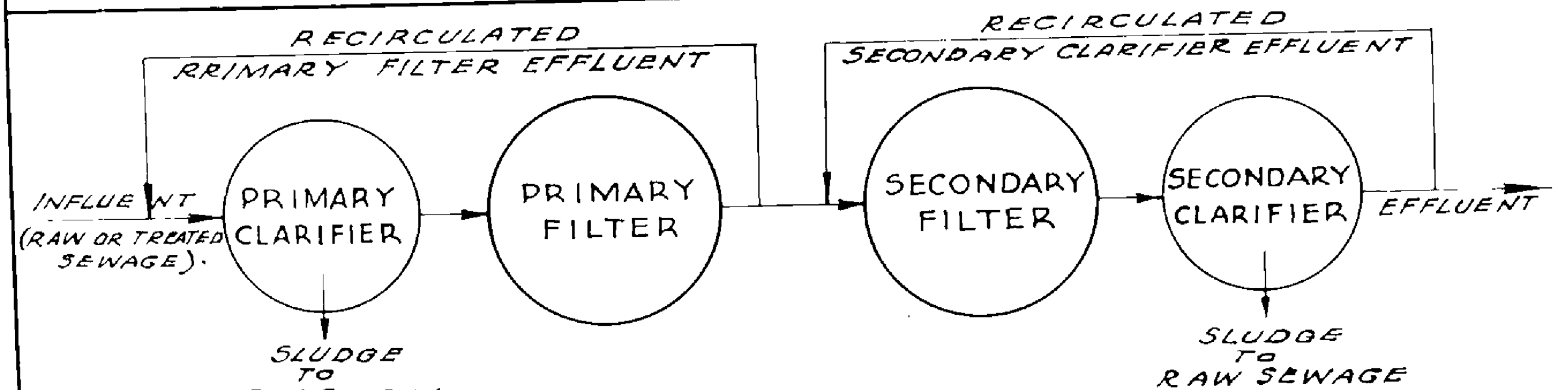
SINGLE STAGE INTERMEDIATE TREATMENT.



SINGLE STAGE COMPLETE TREATMENT NO. 1.



SINGLE STAGE COMPLETE TREATMENT NO. 2.

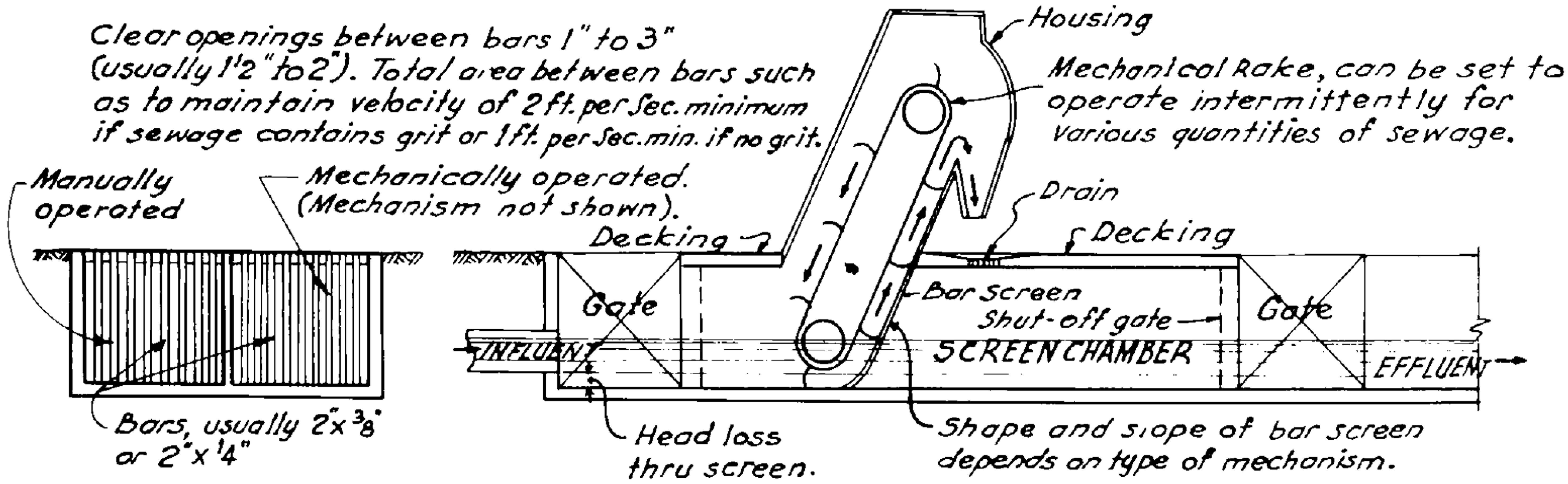


TWO STAGE COMPLETE TREATMENT.

NOTE: See Table C, page 5-40 for approximate efficiencies of systems shown above.
Data from Dorr Company Catalogue.

SEWAGE TREATMENT — BAR SCREENS

COARSE SCREEN TYPE



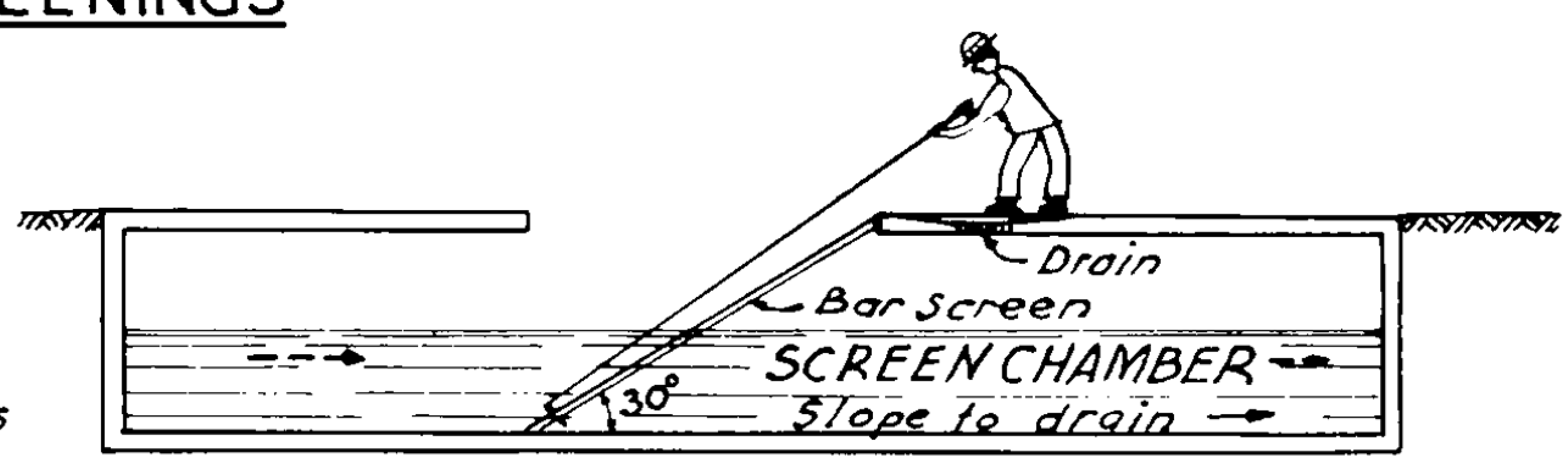
SECTION C-C

SECTION A-A

QUANTITIES OF SCREENINGS*

0.5 to 6 Cu. ft. per million gallons for racks with openings of 2" to ½".

5 to 30 Cu. ft. per million gallons for fine screens (see below) with openings of ¾" to 1/32".

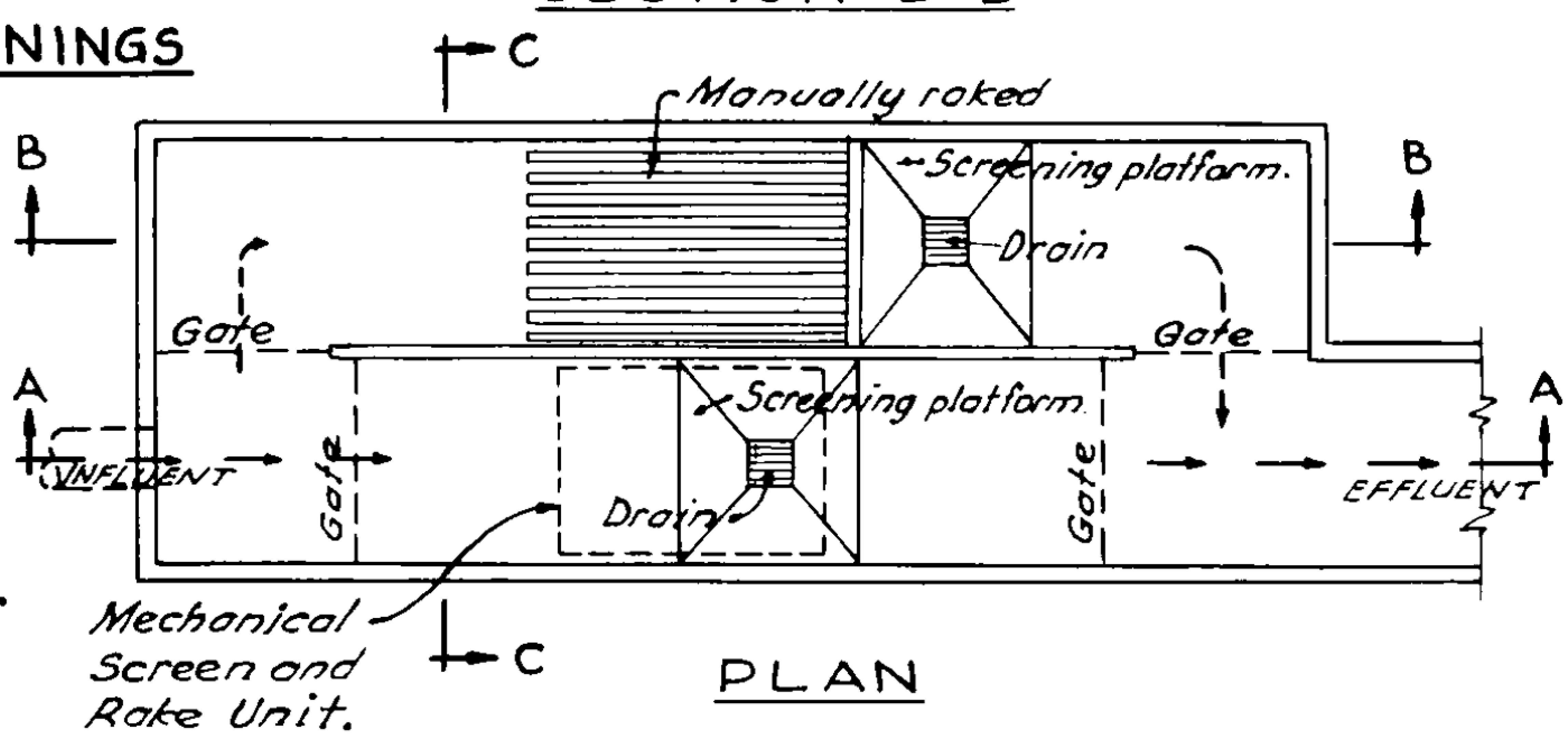


SECTION B-B

DISPOSAL OF SCREENINGS

By burial or incineration.

When quantities of screenings are not excessive, shredders and grinders are sometimes used (see below) and ground screenings are replaced in the effluent to pass through rest of treatment units.



PLAN

FINE SCREEN TYPES : (Clear openings ⅛" or less).**
Net submerged open area, measured below the normal operative level of sewage in the screen chamber, of not less than 2 Sq. ft. per million gallons average daily flow of sewage from separate sanitary sewer systems, and 3 Sq. ft. per million gallons for combined sanitary and storm sewer systems.

SHREDDERS AND GRINDERS : Manufactured in two types:
a.) For grinding solids already removed from sewage by screenings.
b.) For grinding solids as sewage flows through the device, in some cases replacing the screening process. Head loss for this type = 3" to 13". See Pg. 5-61.

*Adapted from Metcalf & Eddy, American Sewerage Practice, McGraw-Hill.
** Compiled from New York State Board of Health laws.

SEWAGE TREATMENT - GRIT CHAMBERS-1

TABLE A — APPROXIMATE SETTLING VELOCITIES IN INCHES PER MINUTE FOR SEWERAGE TEMPERATURE OF 50°F.

KIND OF PARTICLE.	SPECIFIC GRAVITY	DIAMETER, IN mm.						
		1.0	0.5	0.2	0.1	0.05	0.01	0.005
QUARTZ SAND.	2.65	240	127	50	18	4	0.2	0.04
SEWAGE SOLIDS.	1.2	29	15	5	1	0.6	0.02	0.005

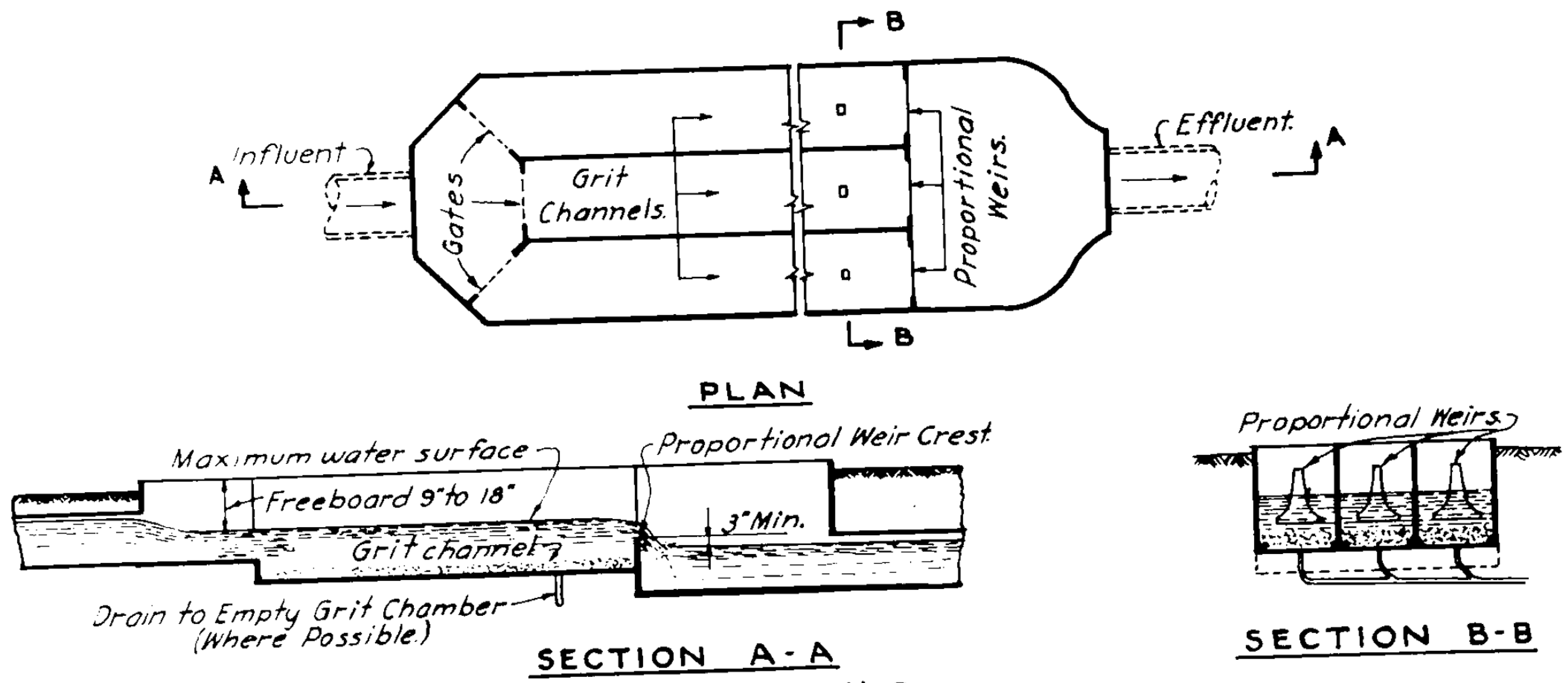


FIG. B. — GRIT CHAMBER DETAILS.

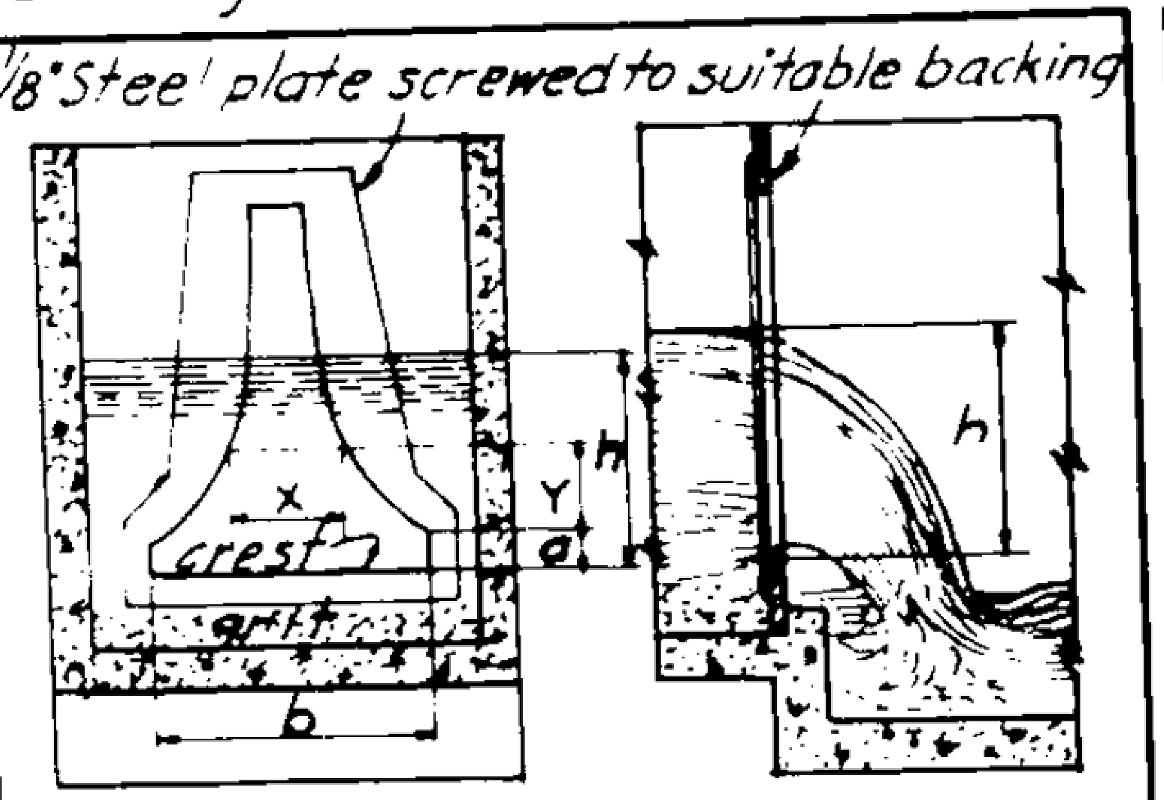
NOTES: 1. Grit Chambers are needed with combined sewerage systems or where industrial wastes and illicit storm drainage carry sand and other heavy inert matter into sewage.

2. Velocity channels and proportional weirs so designed to maintain a velocity of 1 foot per second in channel for all rates of flow.

3. Cross Section required equals rate of sewage flow (cu. ft. per sec.) divided by velocity (in ft. per sec.) + depth for grit storage and freeboard.

4. Overflow Rate or rate of sewage flow per unit of surface area (gals. per day per sq. ft. of surface) = 900 times settling rate of smallest particle it is desirable to remove.
** Generally 0.2 mm of sand.

5. Amount of storage for Grit - combined sewers - 10 to 30 cu. ft. per million gals.; separate sewers 2 to 10 cu. ft. per million gals. Size of storage space depends on proposed interval between cleanings.



ELEVATION (From Upstream Side) CROSS SECTION (Through ℄)

FIG. C- PROPORTIONAL WEIR.

FORMULAS FOR DESIGN OF PROPORTIONAL WEIRS.*

(1.) $Q = 4.97a^{\frac{1}{2}}b\left(h - \frac{a}{3}\right).$

(2.) $\frac{x}{b} = 1 - \frac{2}{\pi}\arctan\sqrt{\frac{y}{a}}$

Q = Quantity of flow in cu. ft. per sec.
For explanation of other symbols see Fig. C at left.

TABLE D- VALUES OF Y/a AND X/b

Y/a	X/b	Y/a	X/b	Y/a	X/b
0.1	0.805	1.0	0.500	10	0.195
0.2	0.732	2.0	0.392	12	0.179
0.3	0.681	3.0	0.333	14	0.166
0.4	0.641	4.0	0.295	16	0.156
0.5	0.608	5.0	0.268	18	0.147
0.6	0.580	6.0	0.247	20	0.140
0.7	0.556	7.0	0.230	25	0.126
0.8	0.536	8.0	0.216	30	0.115
0.9	0.517	9.0	0.205		

** From Sewage Treatment by Imhoff & Fair.
* From Sutro Weir Investigations by E. Soucek, H.E. Howe & F.T. Mavis. p.679 Engineering News Record Nov. 12, 1936.

SEWAGE TREATMENT- GRIT CHAMBERS-2

GRIT CHAMBER & PROPORTIONAL WEIR - EXAMPLE OF DESIGN

GIVEN: A separate sewer system.- Average Flow = 4 cu ft/sec.; Peak Flow = 10 cu ft./sec.
Average accumulation of grit = 6 cu.ft./million gallons of sewage.

REQUIRED: Size of channels and proportional weirs.

SOLUTION

Channel Section.

1. Number of units: Grit chamber will consist of three units; two to accommodate peak flow, the third will be a standby unit.

2. Peak flow in each channel = $\frac{10 \text{ cu. ft./sec.}}{2}$ = 5.0 cu. ft./sec.

3. Cross-sectional Area: Q = 5.0 cu.ft./sec.; Velocity = 1 ft./sec. (see note #2 on pg. 5-44).
Area above crest of weir (exclusive of freeboard) = $\frac{5}{1}$ = 5.0 sq. ft.

4. Settling velocity of a 0.2 mm. particle of sand from Table A p. 5-44 is found to be 50"/min.

5. Overflow rate: From note #4 on p. 5-44 Overflow rate = 900 x 50 = 45,000 gal./day./sq.ft. or 0.07 cu.ft./sec./sq.ft.

6. Surface Area: Each channel requires $\frac{5 \text{ cu.ft./sec.}}{0.07}$ = 71.0 Sq. ft.

7. Depth and width: Assuming a depth of 2.5 feet (above crest of weir exclusive of freeboard).
Width = $\frac{5.0 \text{ sq.ft.}}{2.5}$ = 2.0 ft.

8. Length of channel: Length = $\frac{71.0 \text{ sq. ft. (surface area)}}{2.0 \text{ ft. (width)}}$ = 35.5 ft.

9. Volume of Grit Storage: Assume 6" below crest of weir for storage of grit.
Storage space in each channel.-
Storage space = $\frac{6}{12}$ x 35.5 x 2 = 35.5 cu.ft.

Storage space required is as follows: 4 cu.ft./sec. = 2.6 million gallons/day.
Grit per day = 6 x 2.6 = 15.6 cu.ft. This means that every second day one channel has to be put out of service to be cleaned.

Proportional Weirs.

1. Values of "a" and "b": Using Equation (1) given on page 5-44 and assuming a value for "a" solve for "b" (b should be of such value as to fit into channel with not less than 4 inches to spare on each side). With Q = 5.0 cu.ft./sec.; h = 2.5 ft. and "a" = 0.12; "b" is found to be 1.18 ft.

2. Values of "x" and "y": To find points on curved sides of weir assume values of "Y." Then substitute in Table D, p. 5-44, find x/b and solve for "X".

3. It is advisable that the designer make a full scale drawing of the proportional weir to serve as a template.

NOTE: Mechanical means of grit removal are generally provided for large installations. Sometimes combination grit and screening chambers are designed and equipped with mechanism for cleaning and removing grit.

SEWAGE TREATMENT—SETTLING TANKS-1

DETENTION PERIOD - BASED ON AVERAGE DAILY FLOW. *	
PRIMARY SEDIMENTATION	**HOURS**
Plain sedimentation preceding aeration tank in activated sludge.	0.5 - 1.5
Plain sedimentation preceding trickling filters, contact aeration or sand filters.	2.0 - 2.5
Chemical precipitation.	3.0 - 4.0
Plain sedimentation preceding trickling filters with recirculation of effluent.	6.0 - 7.5
FINAL SEDIMENTATION	
Following low capacity trickling filter.	1.0 - 1.5
Following high capacity trickling filter.	2.0 - 2.5
Following aeration tank in activated sludge.	2.0 - 2.5

OVERFLOW RATES	GALS. PER SQ. FT. PER DAY
Primary Settling Tank.	800 - 1200
Final Settling Tank.	600 - 1000

SIZE OF TANKS

RECTANGULAR SETTLING TANKS.

The length of rectangular tanks should be from three to five times the width.

MAXIMUM LENGTH OF RECTANGULAR PRIMARY SETTLING TANK. **

DETENTION PERIOD	MAXIMUM LENGTH
½ hour	150 feet
¾ hour	200 feet
1 hour	225 feet
1½ hours	250 feet
2 hours	300 feet

CIRCULAR SETTLING TANKS.

Circular settling tanks have been built with a diameter of 200 ft. Most manufacturers make equipment to fit circular tanks varying by 2 ft. intervals up to 30 ft. and by 5 ft. intervals 30 ft. and over.

DEPTH OF TANKS RECTANGULAR OR CIRCULAR.	
Minimum	6 feet
Maximum	10 to 15 feet

General Notes:-

1. Mechanical equipment for sludge and scum collection is generally used for installations for over 1500 persons.
2. The detention period of hopper bottomed tanks should be based upon the liquid capacity above the hoppers and in the case of mechanically cleaned tanks should be based upon the liquid capacity above a plane passing through the tops of the rotating or moving vanes.
3. Tanks should have baffled inlets and outlets.
4. Consult Manufacturers for sizes of equipment being sold; and select proper width, diameter and depths for rectangular and circular tanks.

* Compiled from various State Board of Health laws.

** Data from Link-Belt Co.

SEWAGE TREATMENT—SETTLING TANKS-2

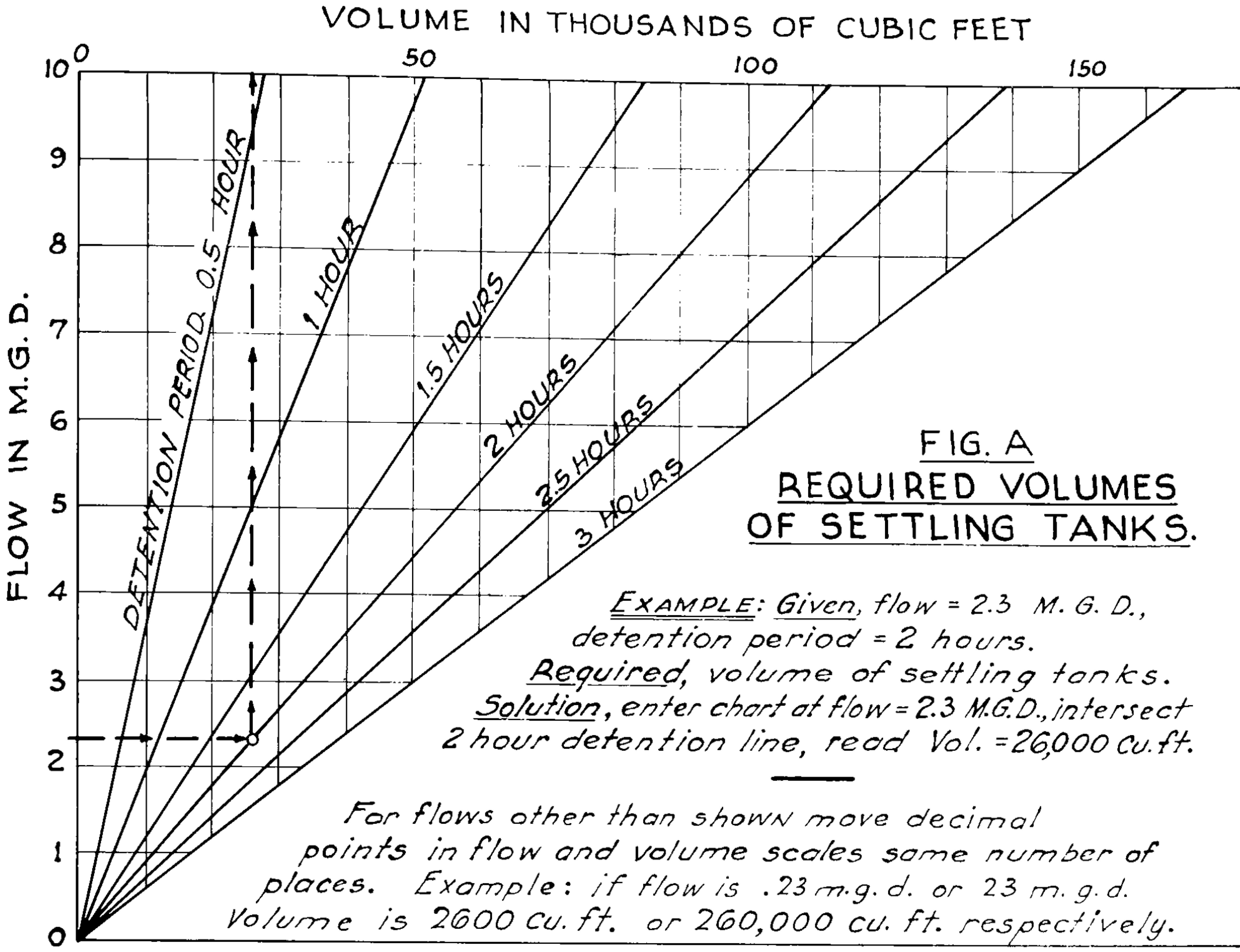


FIG. A REQUIRED VOLUMES OF SETTLING TANKS.

__Example__: Given, flow = 2.3 M. G. D., detention period = 2 hours.
__Required__, volume of settling tanks.
__Solution__, enter chart at flow = 2.3 M.G.D., intersect 2 hour detention line, read Vol. = 26,000 Cu. ft.

For flows other than shown move decimal points in flow and volume scales same number of places. Example: if flow is .23 m.g.d. or 23 m.g.d. Volume is 2600 cu. ft. or 260,000 cu. ft. respectively.

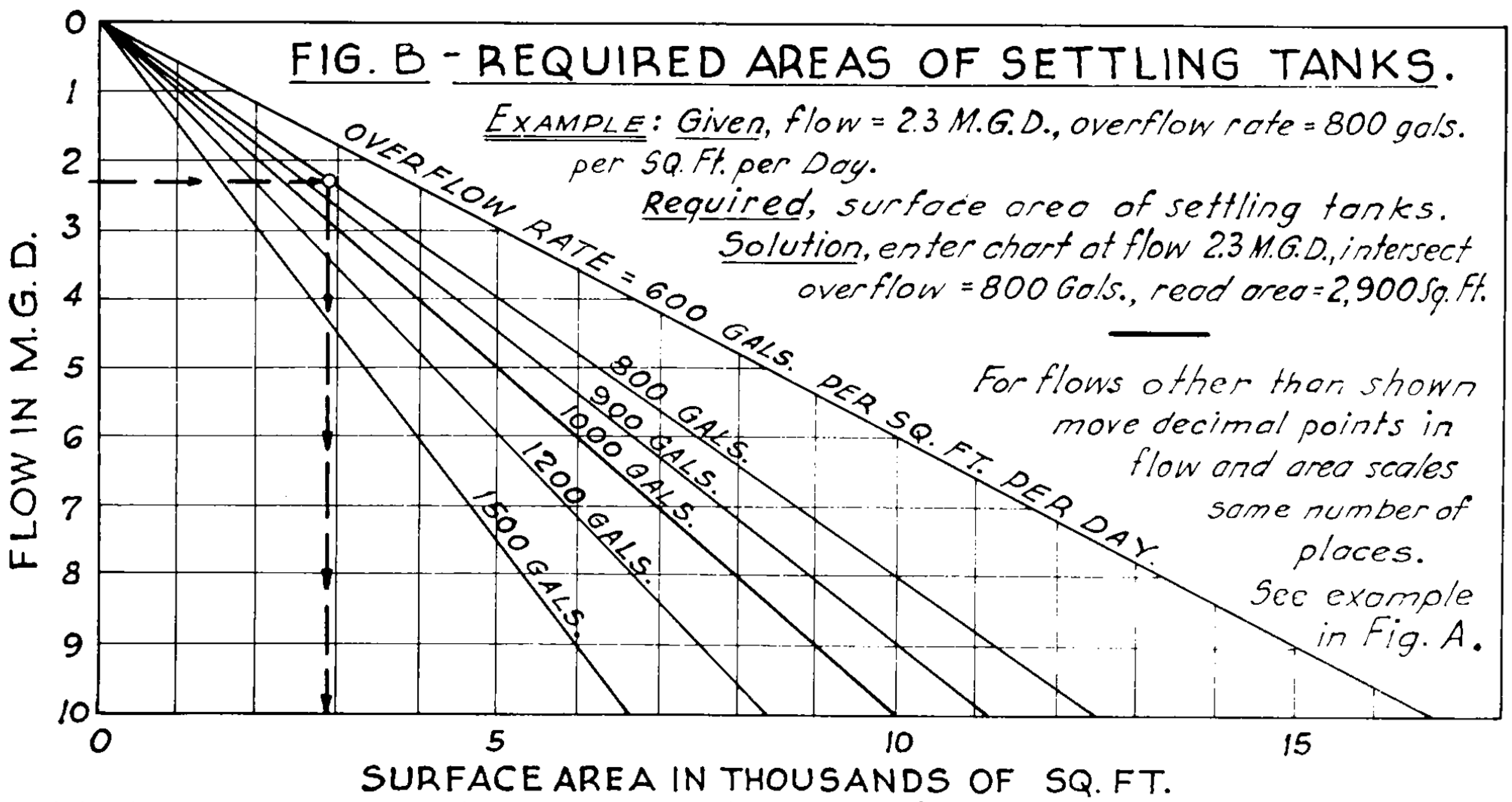


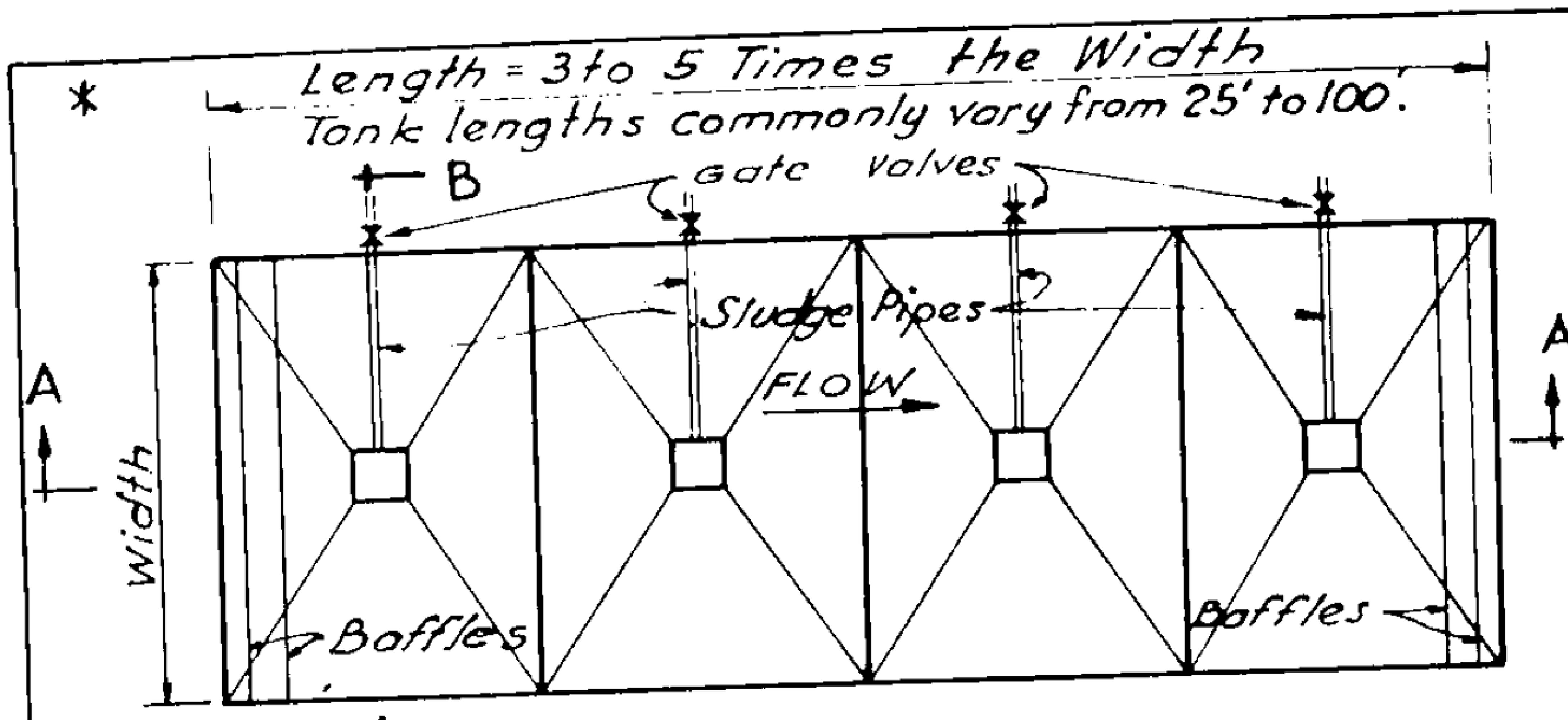
FIG. B - REQUIRED AREAS OF SETTLING TANKS.

__Example__: Given, flow = 2.3 M.G.D., overflow rate = 800 gals. per SQ. Ft. per Day.
__Required__, surface area of settling tanks.
__Solution__, enter chart at flow 2.3 M.G.D., intersect overflow = 800 Gals., read area = 2,900 Sq. Ft.

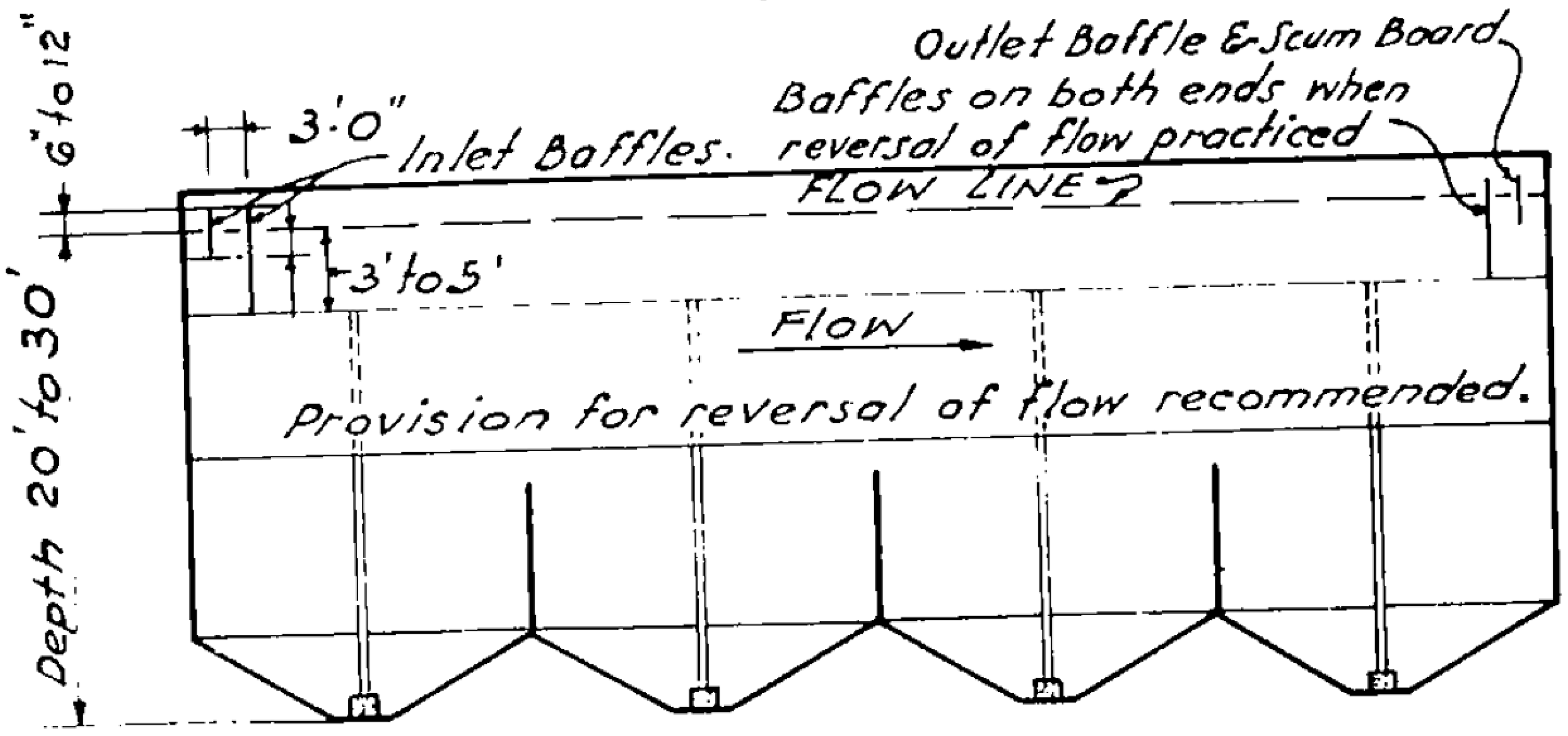
For flows other than shown move decimal points in flow and area scales same number of places. See example in Fig. A.

NOTE: For recommended detention periods and overflow rates. See Page 5-46.

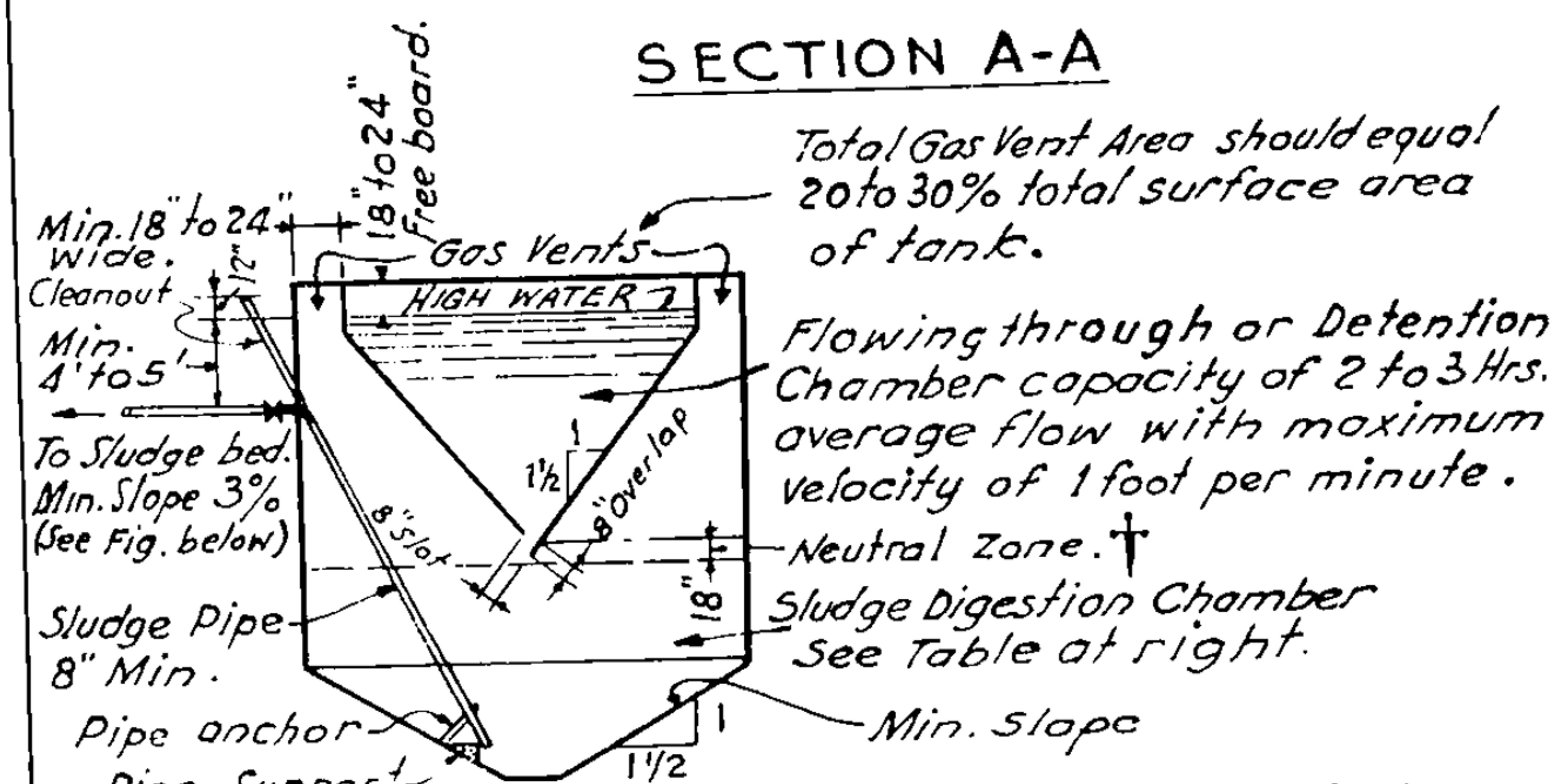
SEWAGE TREATMENT–IMHOFF TANKS



PLAN

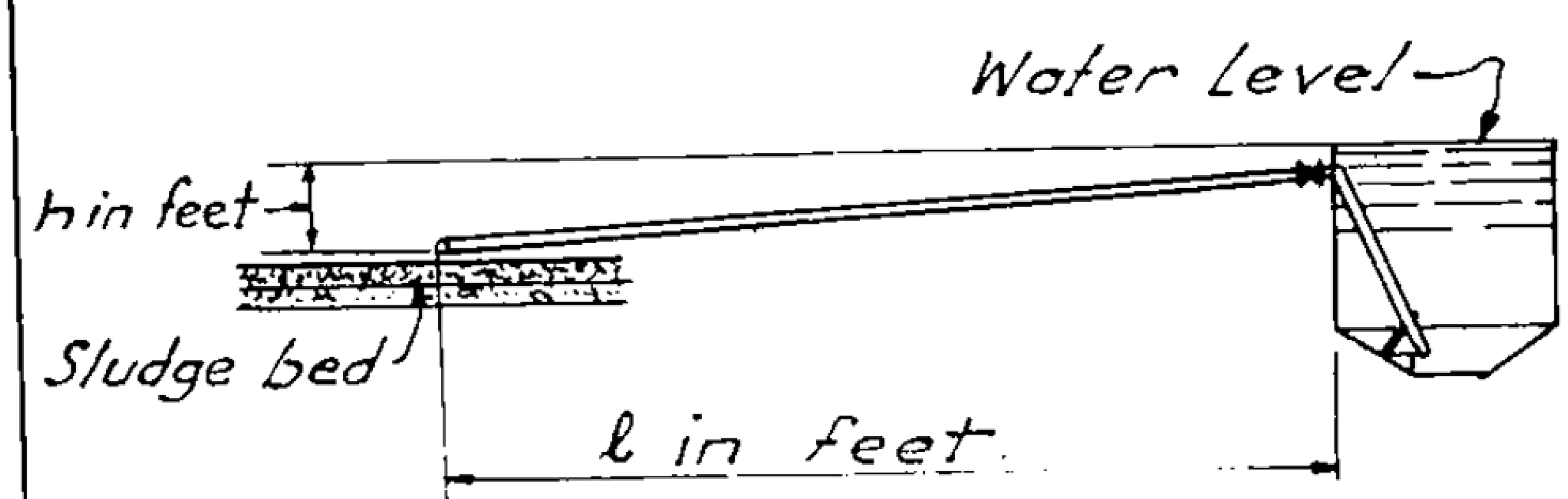


SECTION A-A



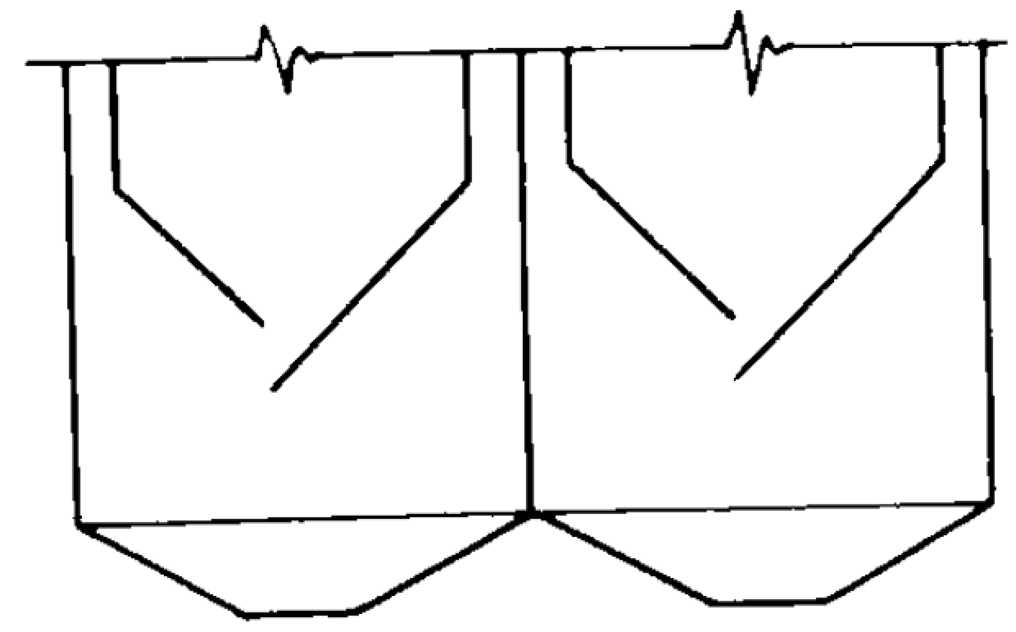
SECTION B-B

†Digesting sludge should not rise above lower level of neutral zone.

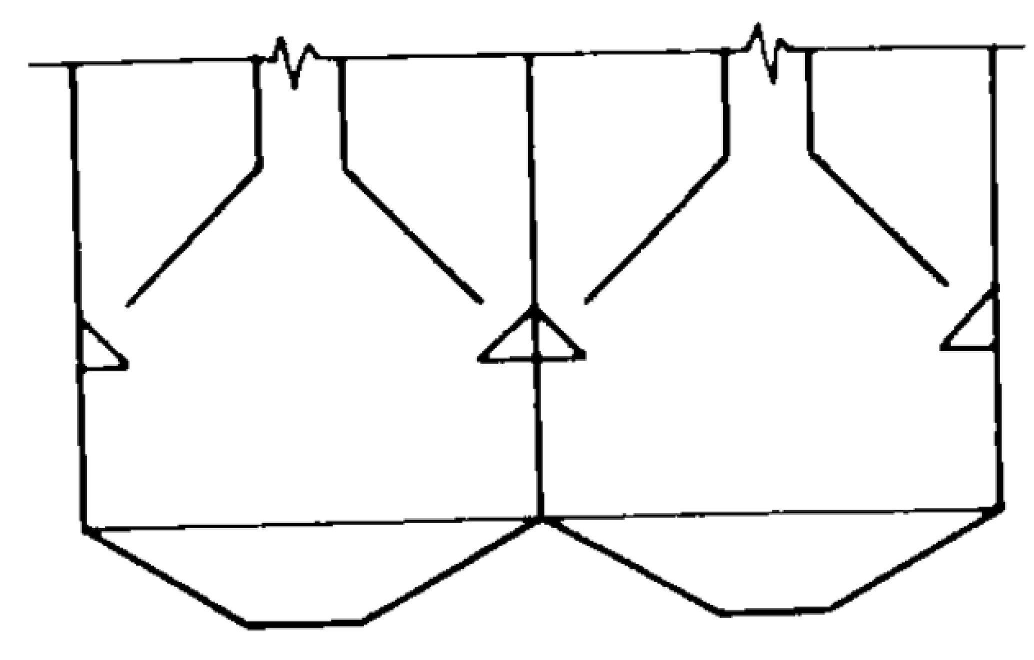


Hydraulic Slope $\frac{h}{\ell}$ should be a minimum of 0.12 ft. per foot.

USUAL ARRANGEMENT OF IMHOFF TANKS.



TYPE I



TYPE II

Design data shown on this page apply for both types.

CAPACITIES FOR IMHOFF TANK SLUDGE COMPARTMENTS RECOMMENDED BY IMHOFF**

CU. FT. PER CAPITA.

SIZE OF CITY SERVED AND CHARACTER OF SEWAGE.	NORTHERN STATES WITH LONG WINTERS.	
	SEPARATE SYSTEM	COMBINED SYSTEM WITH GRIT CHAMBER
Small plants with less than 5,000 population.	2.4	3.6
Normal city plants whose sewage contains some trades wastes.	1.2	1.8
City plants whose sewage contains an abnormal amount of sludge forming trades wastes.	1.8	2.7

The recommended capacities for the larger plants are somewhat lower than used in recent American practice.

NOTES: 1., In warmer climates, where digestion is more rapid, smaller volumes may be used.
2., New York State Department of Health requires 2.0 to 3.0 Cu. Ft. per capita for separate systems and 3.0 for combined systems as a minimum.

* Compiled from various state Board of Health Laws.
** Data from Eng. News, Jan 6. 1916. pg 19 by K. Imhoff

SEWAGE TREATMENT - CHEMICAL PRECIPITATION

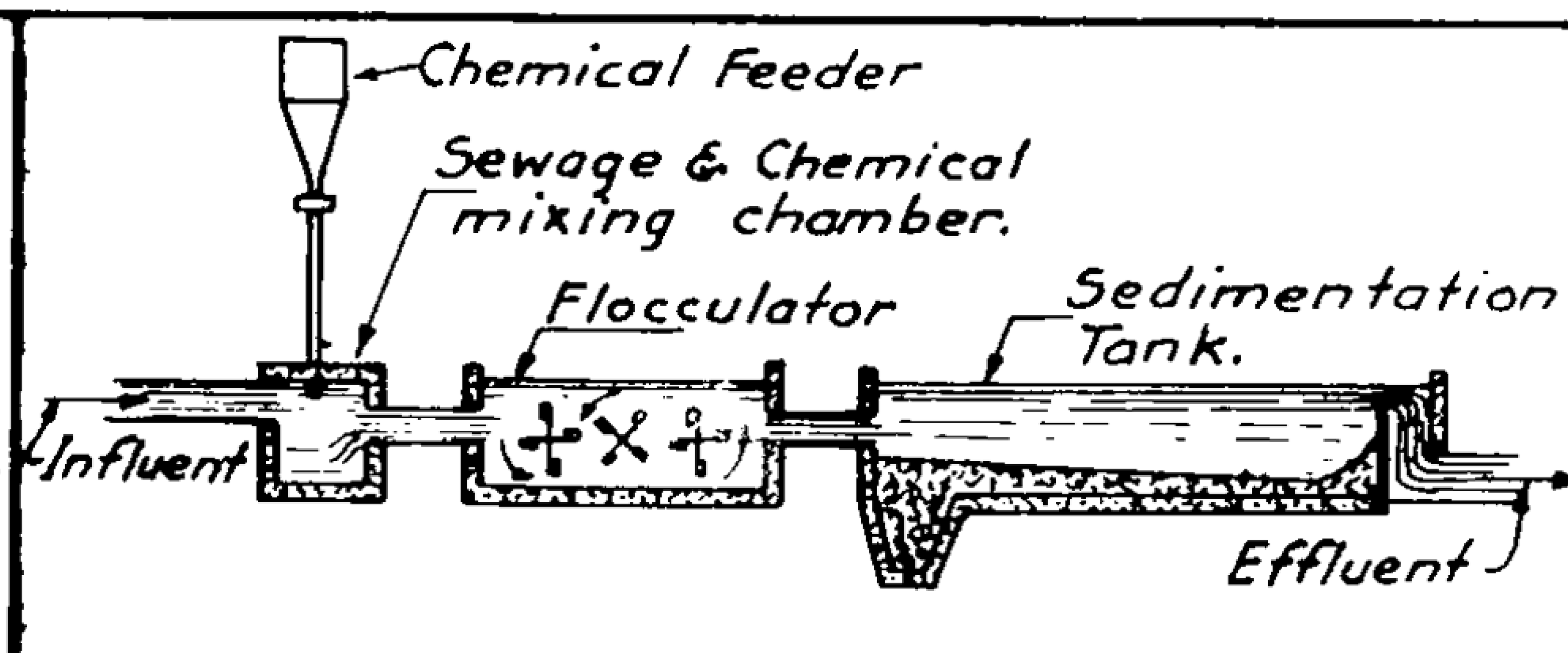


DIAGRAM OF CHEMICAL PRECIPITATION PLANT.

Chemical Precipitation Process consists of mixing chemicals with sewage to produce a flocculent precipitant which increases and hastens sedimentation of the suspended sewage solids. Chemical Precipitation Plants cost much less to construct than any type of secondary treatment plant and are particularly adapted to wide variations in seasonal requirements and conversions of primary plants. The principal purpose of chemical treatment is to reduce suspended solids and B.O.D. and to obtain a clarified and colorless effluent. For comparative efficiency see Table-C, Pg. 5-40. The sewage is analyzed to determine the kind and quantity of chemicals necessary to obtain the required results. After sewage has passed through screens and grit chambers, chemicals are quickly mixed with it. The mixture flows to the flocculent tank which has a detention period of from 15 to 30 min. It then enters the sedimentation tank, where the detention period is from 1 to 3 hours. If a high bacterial removal is required, the final effluent should be chlorinated.

TABLE A - CHARACTERISTICS OF CHEMICAL COAGULANTS*

CHEMICAL	REMARKS
Ferric Chloride	Preferable for sludge conditioning in activated sludge. Most economical for plants requiring more than 7 tons of iron annually, with facilities for handling it. Available as anhydrous, solid, lump, or as aqueous solution. Can be made locally of chlorine and iron or steel scrap. Floc forms satisfactorily at all temperatures. Suitable for oxidizing H_2S with high pH. Highly corrosive and difficult to handle. Solution must be stored and handled in rubber-lined containers and pipes. Useful in odor and corrosion control, forming iron sulphide with H_2S, and is not absorbed by organic matter. Cheaper than chlorine for the purpose. Coagulates best with pH below 7.0, optimum at 5.5. Generally considered the best coagulant available. Anticipated percentage removal S.S. = 90-95; B.O.D. 80. Dose at optimum pH = 2.0 to 2.5 gr. per gal.
Chlorinated copperas	Good for sludge conditioning in activated sludge. Economical for plants requiring more than 7 tons of iron annually, with facilities for handling it. Poor at pH 7.0; good at 5.5 and 9.0 to 9.5 with dose of 2.5 to 5.9 gr. per gal. Per cent reduction S.S. = 80-90 and B.O.D. = 70-80.
Ferrous sulphate (copperas)	pH greater than 7.7 favors oxidation to ferric hydroxide. Dry-feeders not easily used because of caking, but are used. Tendency for cheaper grades to cake during storage. First cost is relatively low. Widely available as waste product from steel mills. Optimum pH about 9.0 with dose 2.5 to 5.0 gr. per gal Overdose results in undesirable after-precipitation Can be fed in solution form.
Ferric Sulphate (ferrisul)	More efficacious than copperas or chlorinated copperas when used with lime. pH best about 8.0 to 8.5 with dose about 2.5 gr. per gal. Per cent reduction S.S. = 80 and B.O.D. = 60. Can be fed dry or as a liquid.
Alum	Not yet widely used in sewage treatment. Economical and conveniently handled. Can be used with dry feeder. pH range from 6.0 to 8.5; above 7.0 most practical. Dose 5-6 gr. per gal. with per cent reduction S.S. = 80 and B.O.D. = 60.
Clay & Other inert materials Bentonite clay, sand, asbestos fiber, paper, etc.	Not yet tried on plant scale. Dosages of 100 p.p.m. in lab. have given excellent results. Bentonite flocs readily over wide pH range with natural alkalinity. Materials other than bentonite not yet developed practically.
Lime CaO = quick. CaOH = hydrated.	Can be dry fed. Is non-corrosive. Commonly used for upward adjustment of pH. Quicklime must be stored in dry, steel tanks and must be hydrated (slaked) before use. Dry hydrated lime can be stored in any dry place.
Sodium carbonate (Soda ash)	Non-corrosive. Can be fed dry.
Chlorine	Corrosive and toxic. Can be stored in cast iron, lead, glass, or rubber. Requires special dosing equipment. Useful in odor and concrete corrosion control and to control flies and ponding on filters.
Aluminum Chloride	Optimum pH 5.5 and 9.0; gr. per gal. at 9.0 = 3, and at pH of 5.5 = 2.5 to 5.0

TABLE B - AMOUNTS OF CHEMICALS USED & RESULTS AT VARIOUS PLANTS**

Plant	Sewage Flow m.g.d.	Chemical	Treatment, lb. per m.g.	Suspended Solids Raw	Suspended Solids % Removal	5-Day B.O.D. Raw	5-Day B.O.D. % Removal
Coney Island, N.Y.	20.1	Cop. CaO Cl	191 546 105	154	60	112	39
	22.0	Cop. Cl	345 153	169	68.5	108	56
	22.6	F.S. CaO Cl	188 340 101	153	67	98	48
	23.5	Cop Cl	279 135	206	78.7	122	66
New Britain, Conn.	7.8	Cop Cl	281 41.3	173	85.5	156	78.2
New Britain, Conn.	9.1	F.S.	106.3	136	77.9	137	74.4
EL Paso, Tex.	6.0	F.C.	72	339	84	287	63.8
Danville, Ill.	4.5	Alum	373	235	81.4	201	61.5
Dearborn, Mich.	2.6	F.C. CaO	305 250	293	92	174	76
Perth Amboy, N.J.	2.5	F.C. CaO	250 650	240	88	257	61
Butler, Pa.	2.1	Cop. CaO Cl	494 350 107	-----	73	-----	58.7
Shades Valley, Ala.	1.1	Cop Cl	412	80	86	53	87

Cop. = Copperas, CaO = Lime, Cl = Chlorine, F.S. = ferric sulphate, F.C. = ferric chloride.

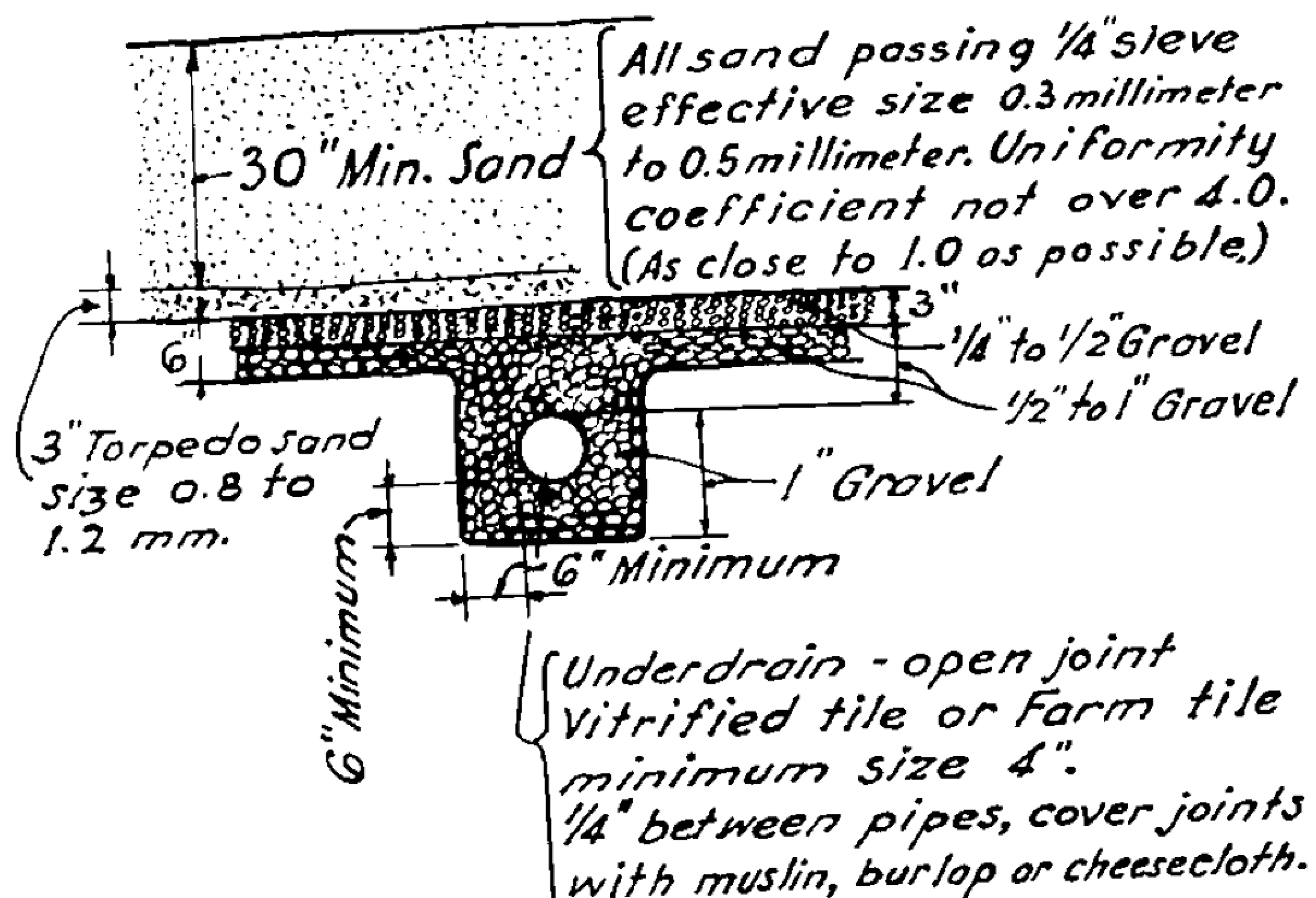
* From Sewerage & Sewage Treatment by Harold E. Babbitt.

** W. Donaldson Chemical Treatment of Sewage Modern Sewage Disposal P. 85 Federation of Sewage Works Assoc.

SEWAGE TREATMENT-INTERMITTENT SAND FILTERS

TABLE A-CAPACITY OF SAND FILTERS.

TYPE OF EFFLUENT	GALLONS PER ACRE PER DAY (AVERAGE FLOW)
Settling tank effluent.	75,000 to 150,000
Trickling filter effluent.	200,000 to 400,000
Activated sludge effluent.	300,000 to 800,000



TYPICAL SECTION OF SAND BED

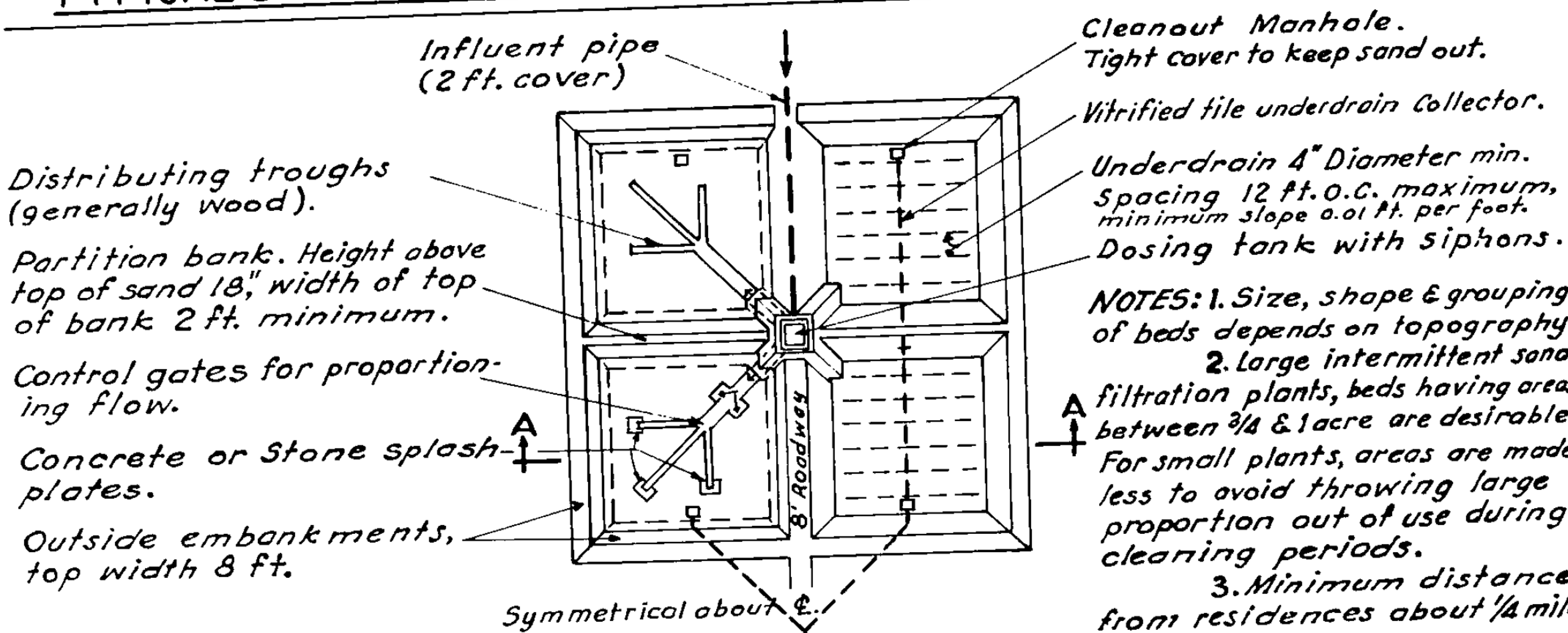
SIZE OF DOSING TANK

1. Capacity of dosing tank should be large enough to flood one unit to a depth from 2 to 4 inches.

2. Each filter bed should receive either 1 or 2 doses per day, preferably one.

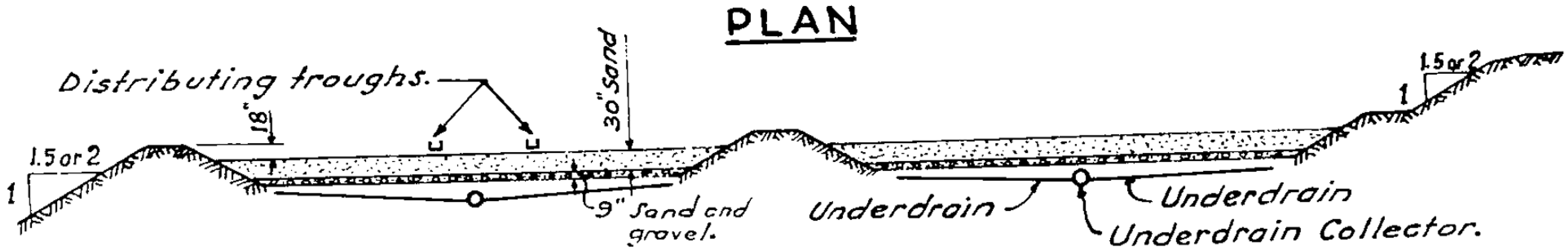
3. Rate of discharge of siphon at minimum head (see page 5-51) should be between once and a half and twice the maximum inflow to the dosing tank from the settling tank.

4. Average rate of dosage should be about 1 cu. ft. per sec. per 5000 sq. ft. area.



NOTES: 1. Size, shape & grouping of beds depends on topography.
2. Large intermittent sand filtration plants, beds having areas between 3/4 & 1 acre are desirable. For small plants, areas are made less to avoid throwing large proportion out of use during cleaning periods.
3. Minimum distance from residences about 1/4 mile.

PLAN



SECTION A-A

FIGURE B - TYPICAL LAYOUT OF SAND FILTERS.

Compiled from various State Board of Health laws.

SEWAGE TREATMENT—SAND FILTER DOSING SIPHONS

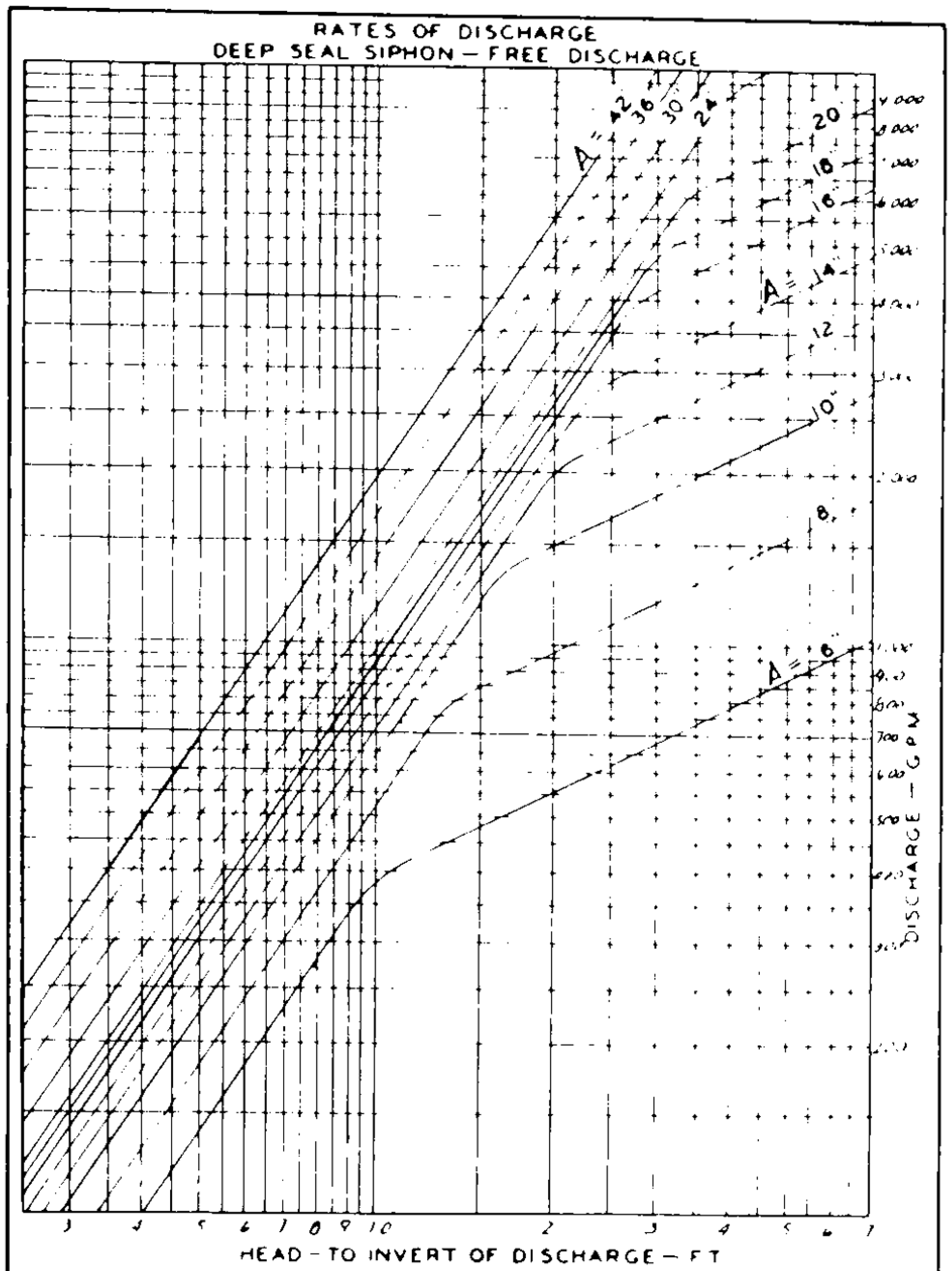


FIG. B RATES OF DISCHARGE FOR SIPHONS DISCHARGING INTO OPEN TROUGHS.

NOTE: *An average of rates at Minimum & Maximum Head will give a fair estimate for use in determining time to empty Dosing Tank.*

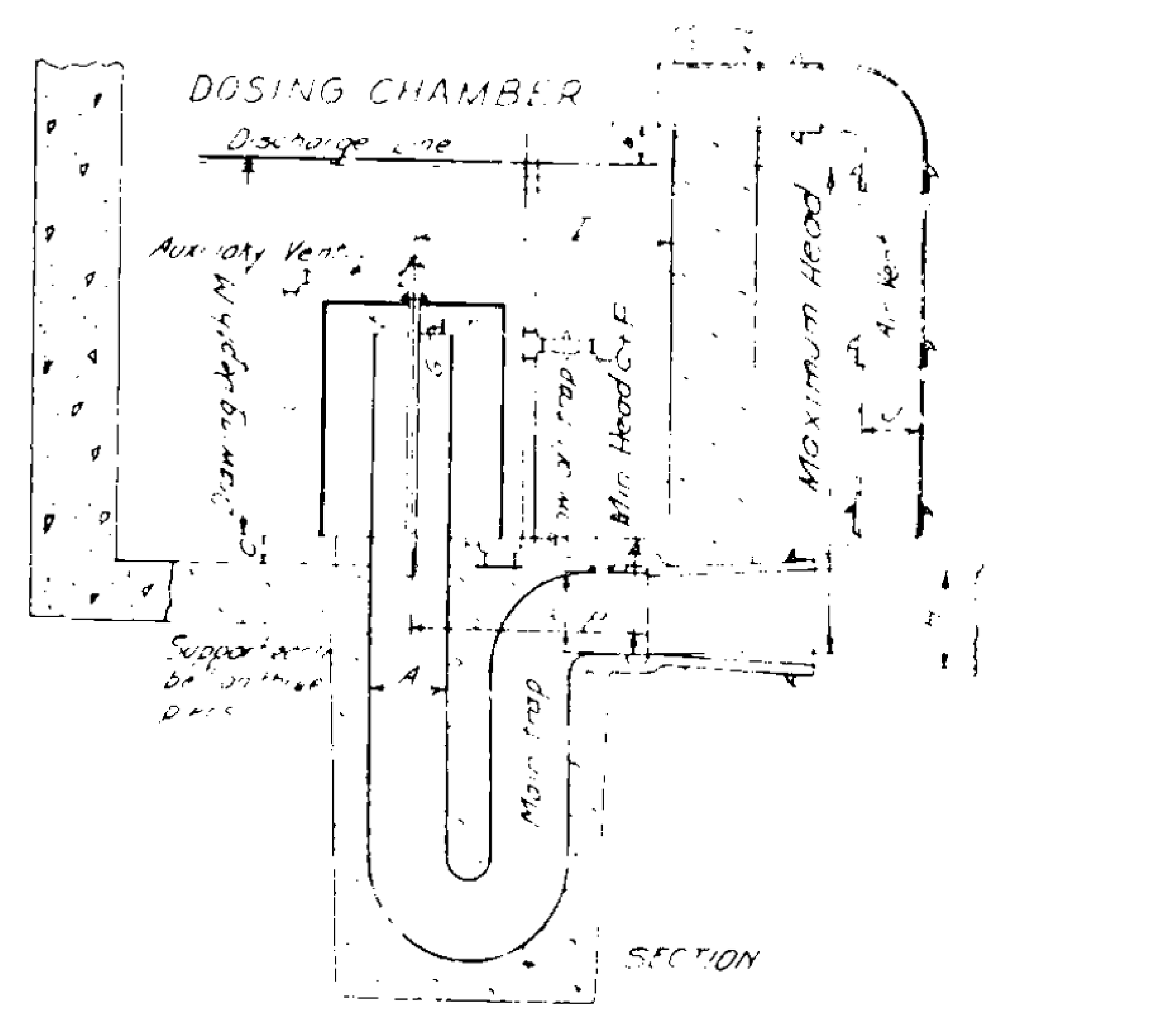


FIG. A — SINGLE SIPHON.

NOTE: Two siphons in same tank can operate alternately.

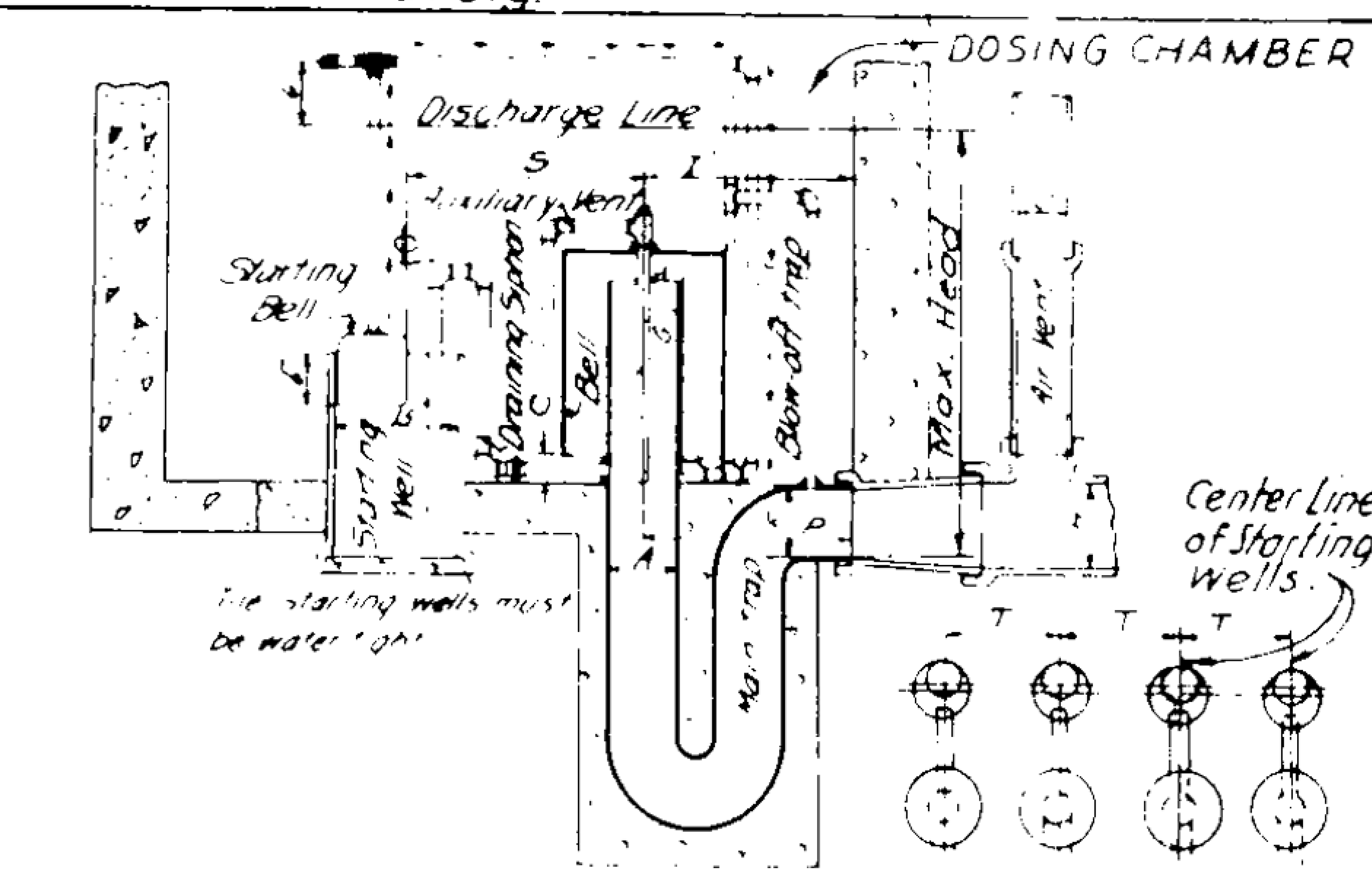


FIG. C - PLURAL ALTERNATING TYPE "A".

NOTE: *Plural Alternating Type "B" works by means of a starting device on vent lines. Has no starting wells or interconnecting pipes like Type "A".*

TABLE D - MINIMUM DISCHARGE & DIMENSIONS OF SIPHONS.

A DIA. INCHES	DISCHARGE IN G.P.M. AT MIN. HEAD	DIMENSIONS IN INCHES.							
		C, E	F	G	H	I, P	J	S	T
5	140	3	5½	1½	6	20	6	27	30
6	270	3	6½	1½	8	21	6	27	30
8	450	3	8½	1½	10	25	6	30	36
10	700	4	10½	2	12	28	8	36	36
12	1200	4	12½	2	14	32	8	36	36
14	1800	5	14¾	2½	16	39	10	39	42
16	2750	6	16¾	3	16	44	10	42	48
18		6	18¾	3	18	48	12	42	48
20		8	20¾	4	20	51	12	48	48
24		8	24¾	4	24	57	14	48	60

NOTE: *Max. Inflow into Dosing Tank must be less than Siphon discharge at min. head or Siphon will not close.*

TAB. E - RESTRICTIONS OF USE OF SIPHONS.

	SINGLE SIPHON	DOUBLE ALTERNATING SIPHON	PLURAL ALTERNATING SIPHON TYPE A	PLURAL ALTERNATING SIPHON TYPE B
Setting		Both Siphons accurately set at same elev.	Traps set parallel or at right angles	Can be set to any position.
Valves	None	None	Provided to cut any No. of Siphons out of operation	Provided to cut any one Siphon out of operation when 4 are used.
Interconnected Piping	No	No	Yes	No
Min. No.	1	2	2	3
Max. No.	1	2	10	4
Min. Drawing Depth	Depends on Size		3'0"	3'0"
Max. Drawing Depth.	Depends on Size		5'0"	5'0"

Data from Pacific Flush Tank Company, Bulletin No. 124.

SEWAGE TREATMENT — TRICKLING FILTERS

TABLE A - DESIGN DATA FOR TRICKLING FILTERS.

ALLOWABLE LOADING - B.O.D. IN POUNDS PER ACRE FOOT PER DAY		
B.O.D. OF RAW SEWAGE. p.p.m.	LOW OR STANDARD RATE FILTERS	HIGH RATE FILTERS.* (BASED ON 3' DEPTH BIO-FILTRATION PROCESS) FOR GREATER DEPTH USE LOWER B.O.D. LOADINGS.
Less than 100	200	1300
100 to 150	—	2400
150 to 300	250	3200
300 to 450	—	4000
450 to 600	450	4800

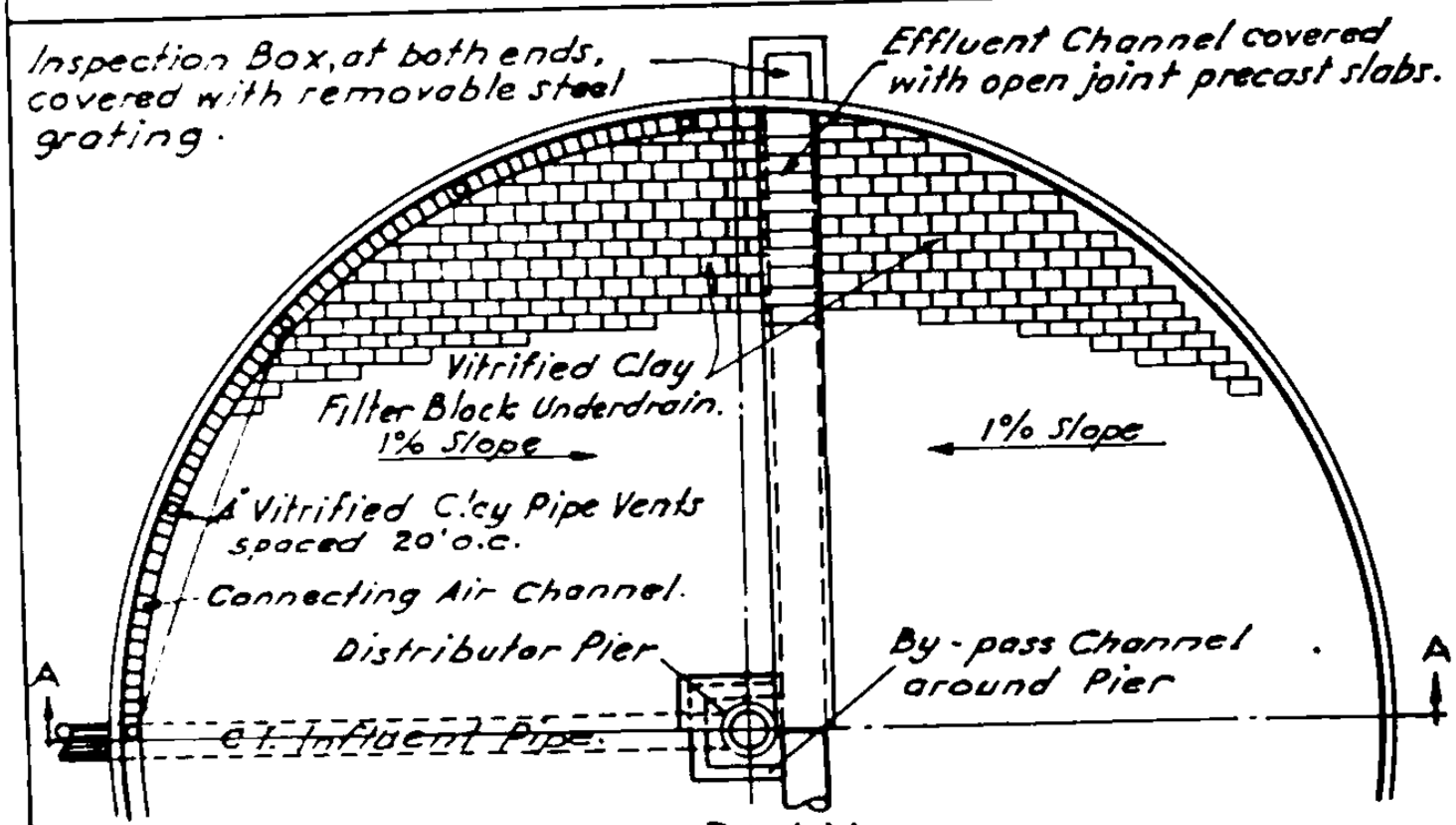
ITEM	STANDARD OR LOW RATE FILTERS	HIGH RATE FILTERS
Depth of Filter Stone.	Min. 5.5' Max. 9' } Average 6' to 8'	3'-0"
Size of stones, uniform throughout.	1½" to 3"	2" to 3½" Primary 1½" to 2½" Secondary
Fixed Nozzles.	Fixed nozzles always used in past.	Never used.
Rotary Distribution.	Present practice favors rotary distr.	Always used.
Dosing Tank.	Always used.	Never used.
Recirculated Flow. (Requires use of Pumps)	Never used.	Always used.

*When using high rate filtration processes (bio-filtration, aero-filtration, etc.) manufacturers should be consulted to obtain charts showing values of loading on filter which they will guarantee to produce the results required. Permissible B.O.D. loading of filter depends on depth of filter, strength of sewage and the degree of removal desired.

EXAMPLE: Given: 1. Population = 10,000. 2. Residential town including ordinary commercial establishments - separate sanitary sewers.

Required: Volume of rock for standard low rate trickling filter.

Solution: 1. From Tab. A Pg. 5-40 pounds of B.O.D. per capita daily = 0.17.
2. Total B.O.D. requirement of raw sewage = 10,000 × 0.17 = 1700#.
3. From Tab. C. Pg. 5-40 - Allow 35% B.O.D. reduction for primary settling tanks, leaving 1700 × 0.65 = 1100# to be applied on filter.
4. From Pg. 5-23 - we find an average flow of 100 Gals. per capita per day.
5. B.O.D. of raw sewage = $\frac{0.17}{100 \times 8.35} \times 1{,}000{,}000 = 204$ p.p.m. From Tab. A above use a value of loading on filter of 250 pounds per acre foot per day.
6. Volume of rock required = $\frac{1100}{250} = 4.4$ acre feet.



PLAN

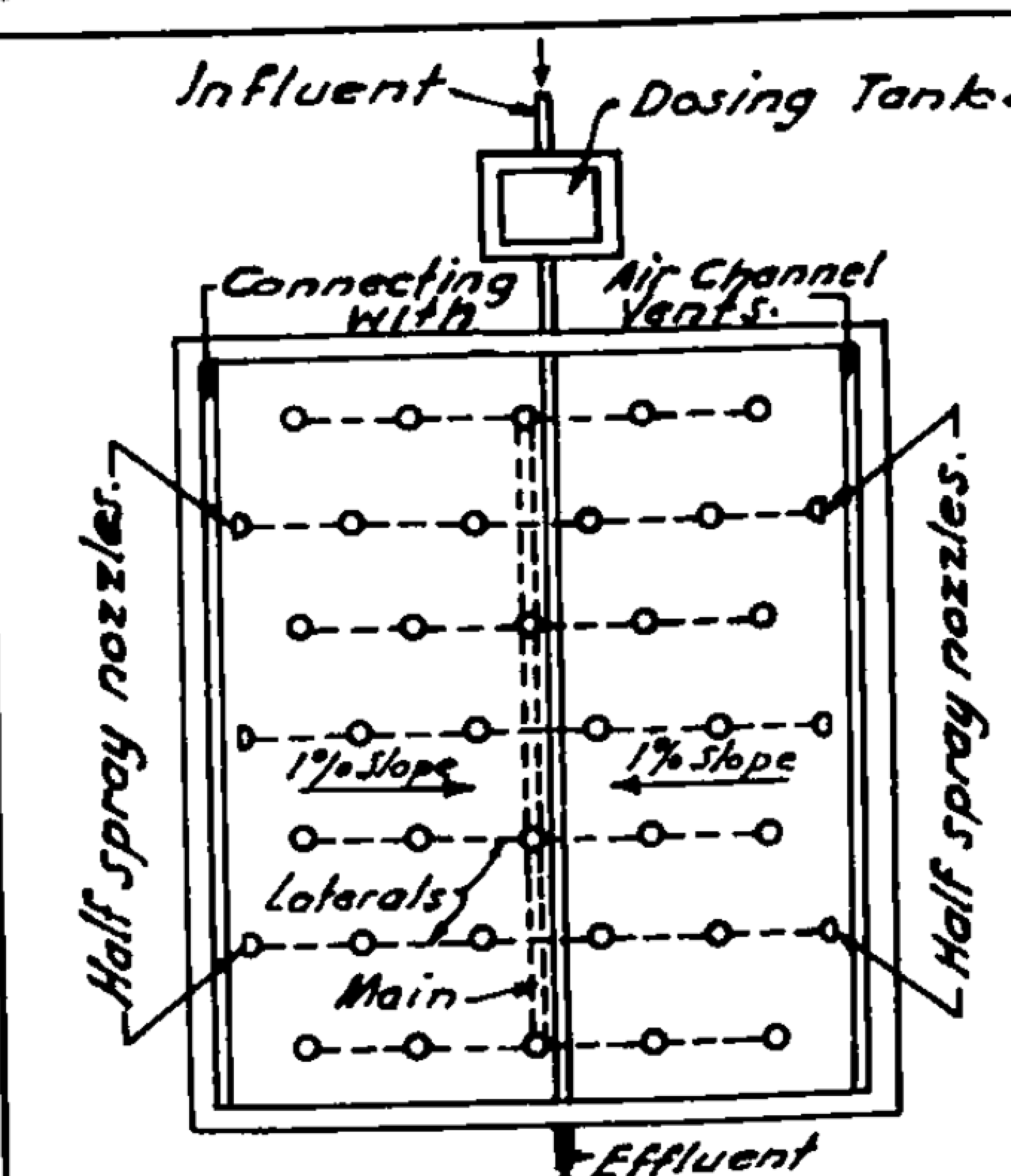
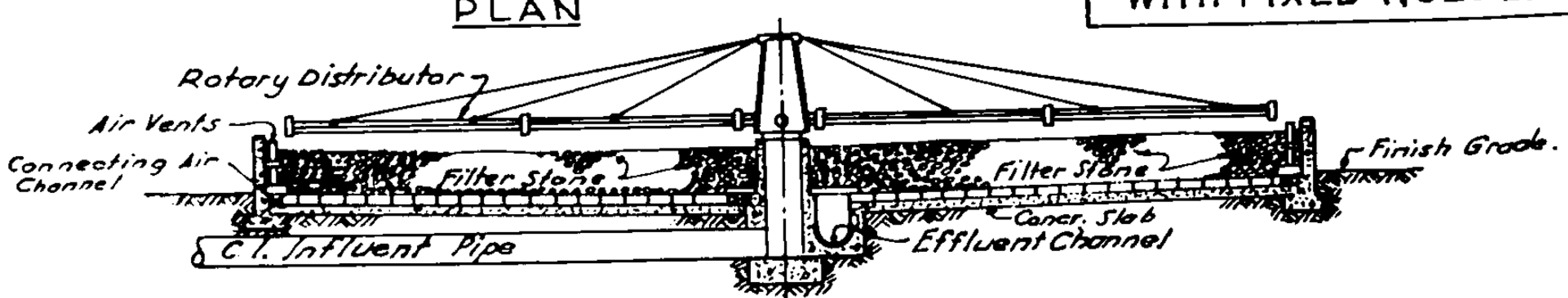


FIG. B-RECTANGULAR FILTER WITH FIXED NOZZLES.



SECTION A-A

FIG. C - CIRCULAR FILTER WITH ROTARY DISTRIBUTOR.

SEWAGE TREATMENT - ACTIVATED SLUDGE-1

EXPLANATION OF ACTIVATED SLUDGE PROCESS:- This method is based upon the practice of allowing a large number of bacteria to multiply in sludge under conditions which are generally anaerobic (putrifactive). New conditions which are favorable to the development of aerobic bacteria and microscopic organisms are then created by aerating the sludge. When this "activated sludge" is mixed with sewage and the mixture is aerated the organic matter in the sewage is changed to harmless compounds by oxidation. After the mixture leaves the aeration tanks it is discharged into final sedimentation tanks where the sludge settles. A portion of the settled sludge, amounting to from 10 to 50 per cent of average sewage flow, is returned to the inlet of the aeration tanks and mixed with the influent sewage. See Page 5-54 for basis of design of different types of systems. See Page 5-55 for air flow data.

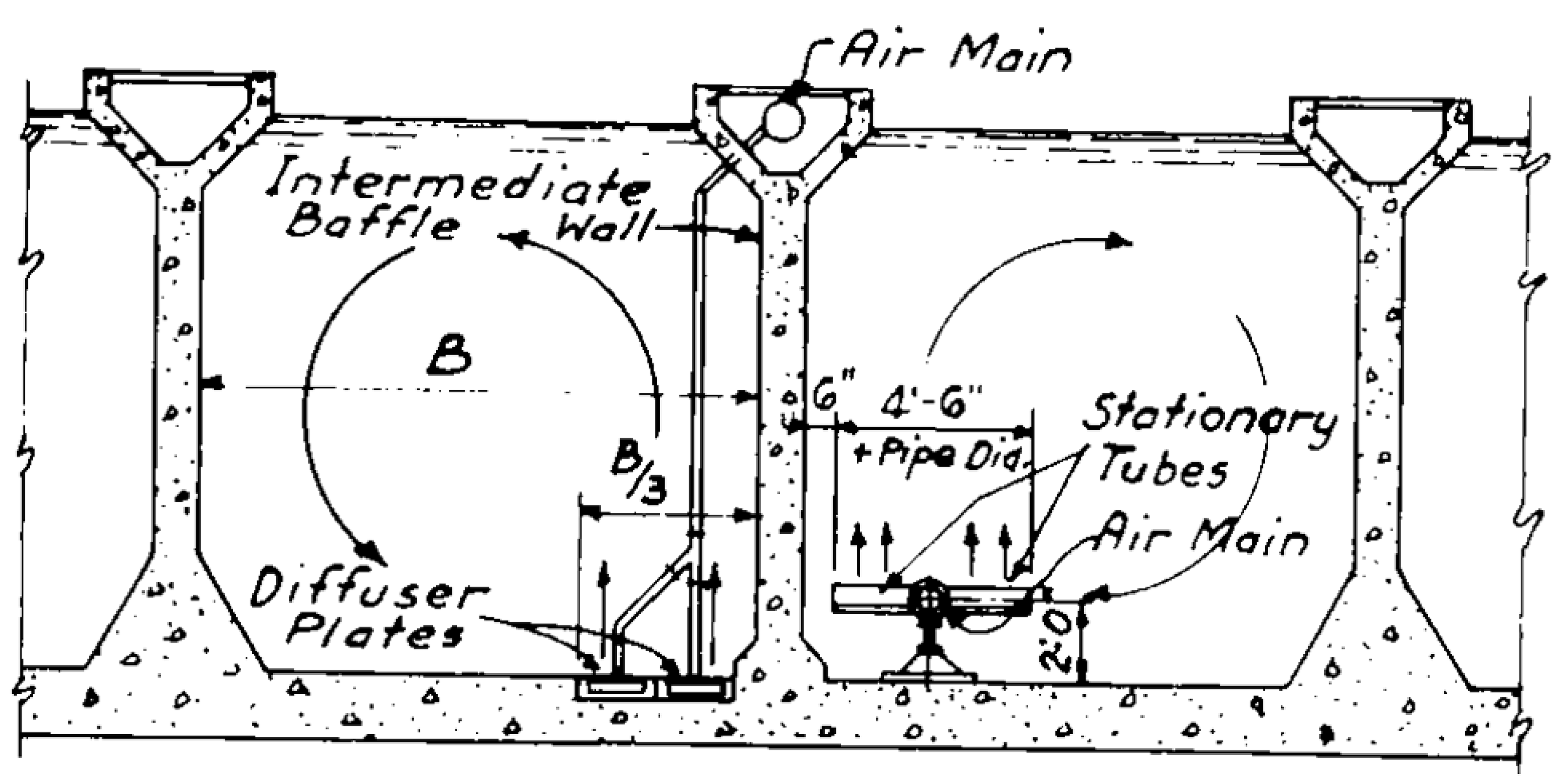


FIG. A - AERATION TANKS, DIFFUSER PLATE OR STATIONARY TUBE** TYPE.

Diffuser plates or tubes on one side supply air and cause spiral turbulent flow.

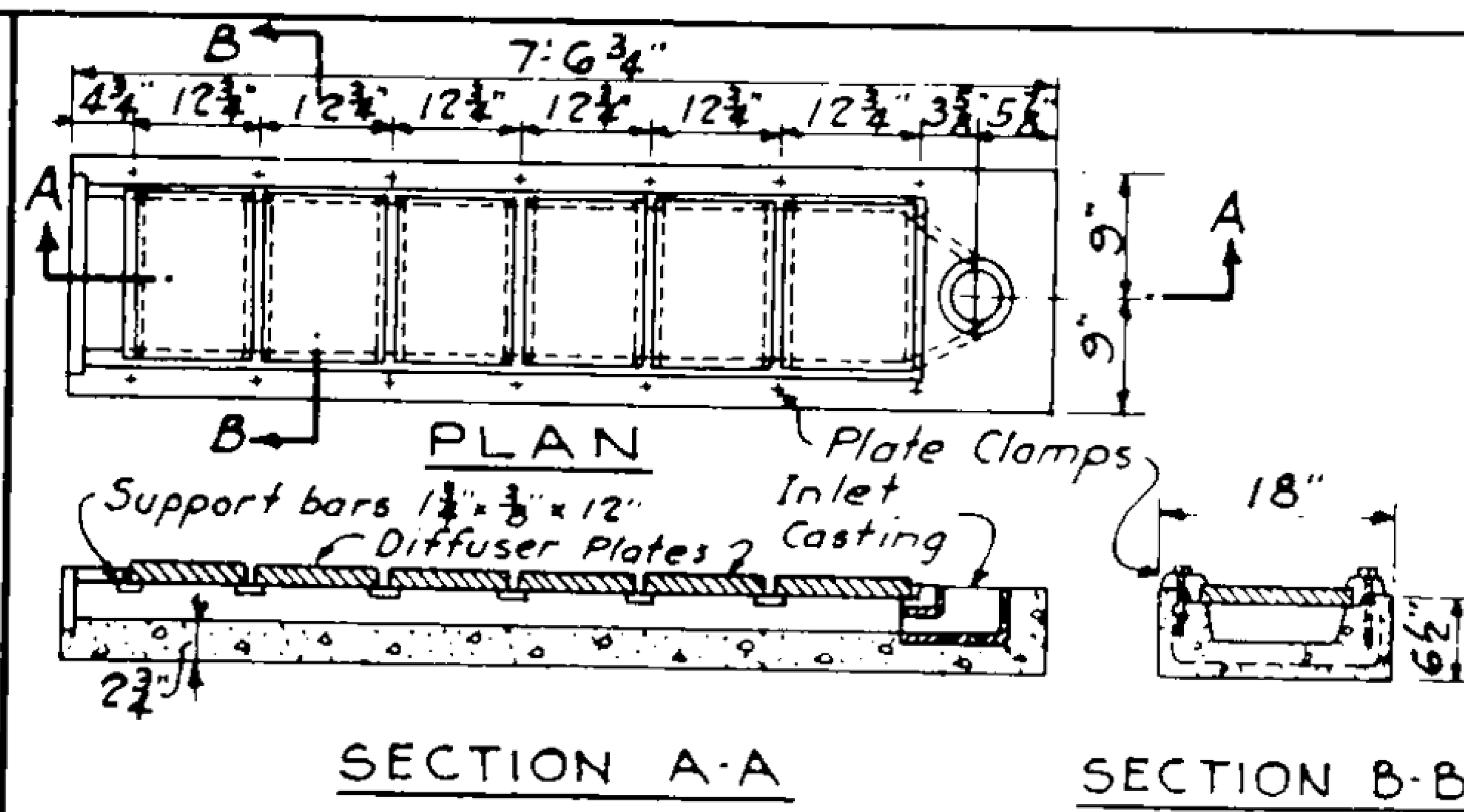


FIG. B - DETAILS OF A DIFFUSER PLATE CONTAINER.*

Used for spiral flow as shown in Fig. A. These containers may be made of aluminum or reinforced concrete. The plates rest on suitable gaskets, are held in place by clamps.

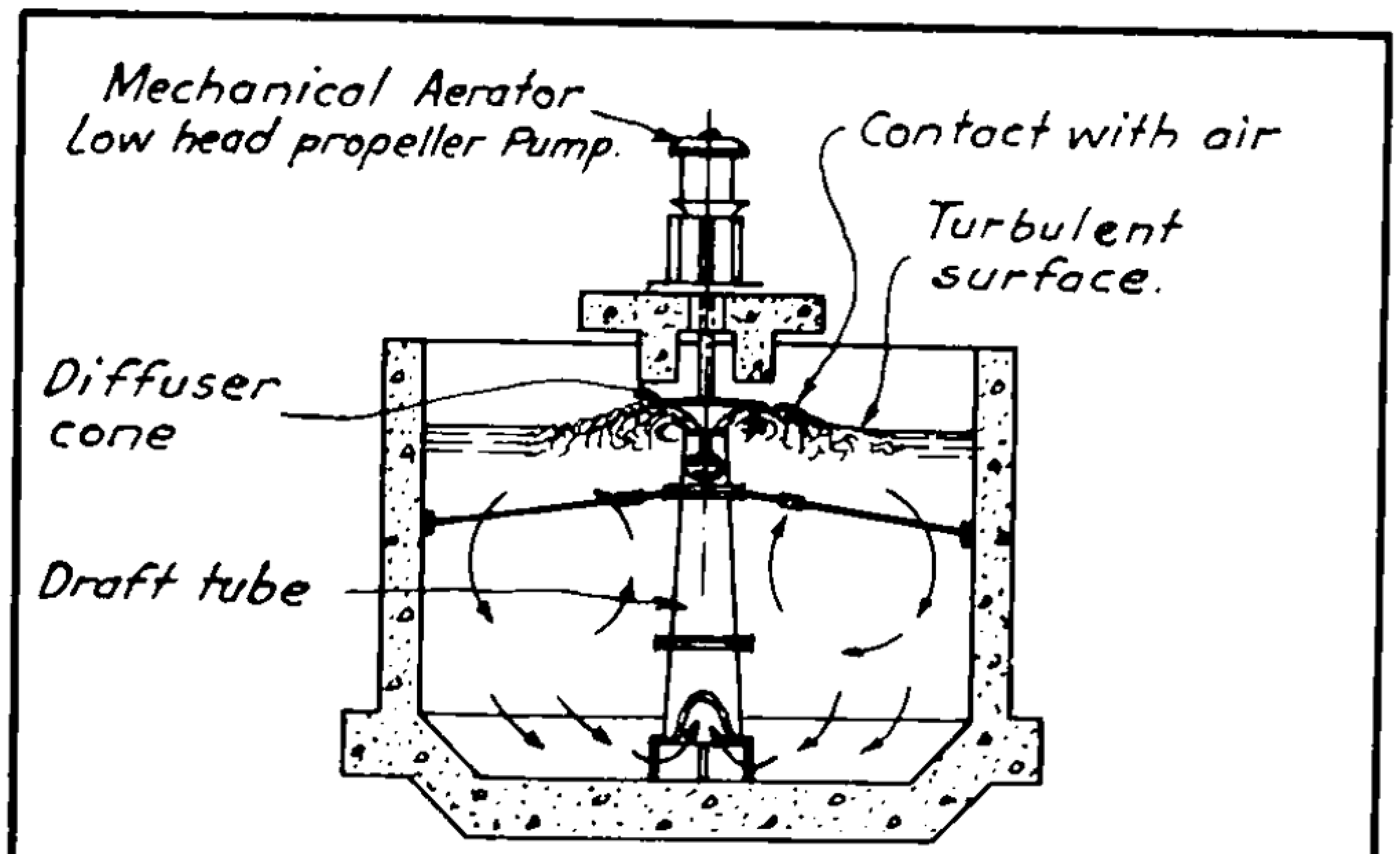


FIG. C - AERATION TANK - MECHANICAL.**

Low head propeller pump throws sewage in draft tube against diffuser cone, providing aeration at surface of tank by direct contact and surface agitation.

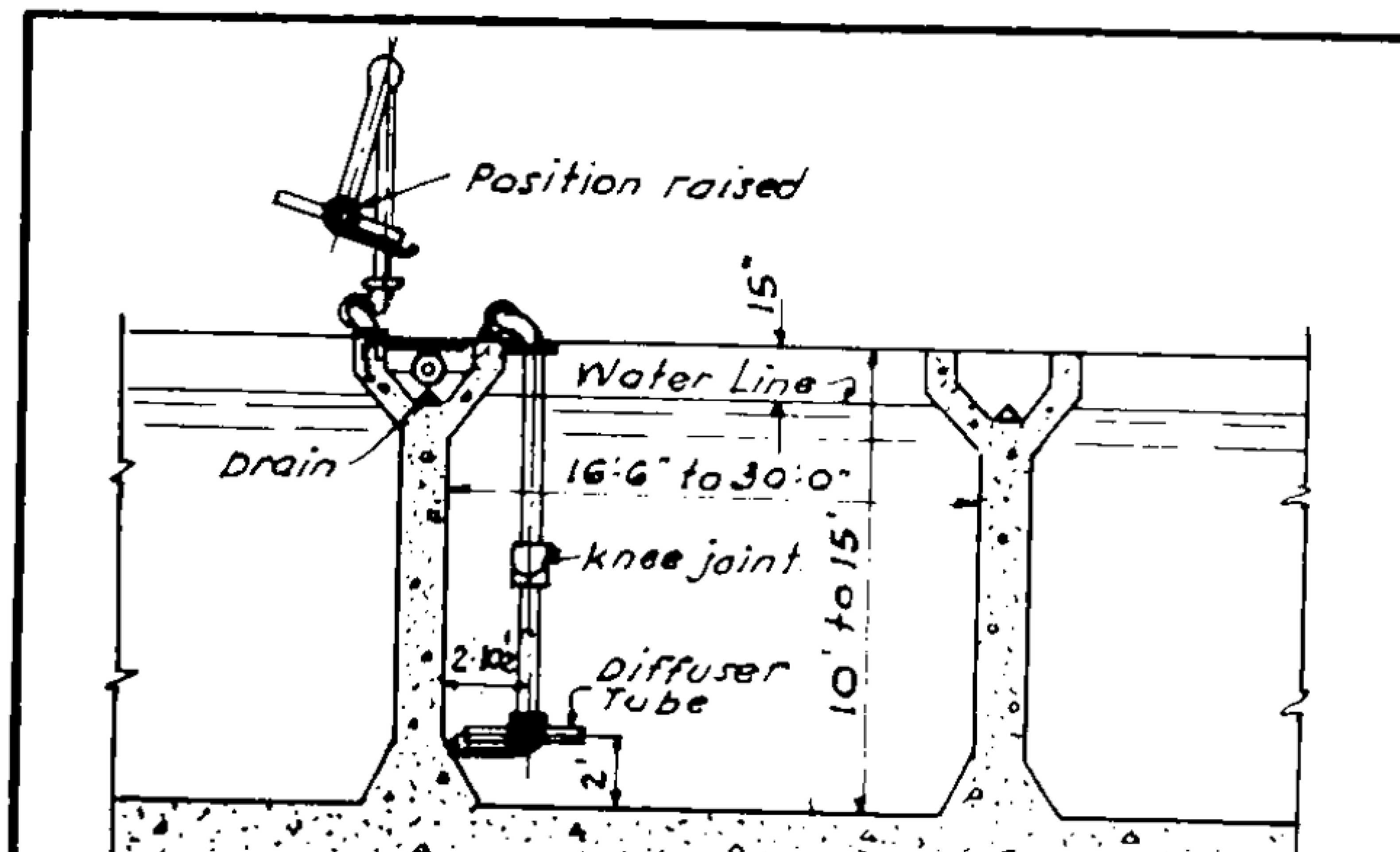


FIG. D - AERATION TANK - SWING DIFFUSERS.**

Diffuser tubes on one side supply air and cause spiral turbulent flow.
Tubes may be examined, respaced, cleaned or replaced without emptying tank.

$$\text{Period of Aeration (in hours)} = \frac{\text{Capacity of Tanks (Cubic feet)}}{\text{Volume of Sewage flow + Volume of return sludge per hr. in cu. ft.}}$$

Aeration Tank capacity based on average flow.
Pumps, pipes, flowmeter, etc., designed for maximum flow.

* The permeability of a diffuser plate is determined for the number of cu. ft. of air per minute passing through one sq. ft. of diffuser plate under a pressure equivalent to a 2" column of water when the plate is dry and the temperature is 70°F. Present practice is to use diffuser plates with a permeability from 20 to 50.

** From Chicago Pump Co.

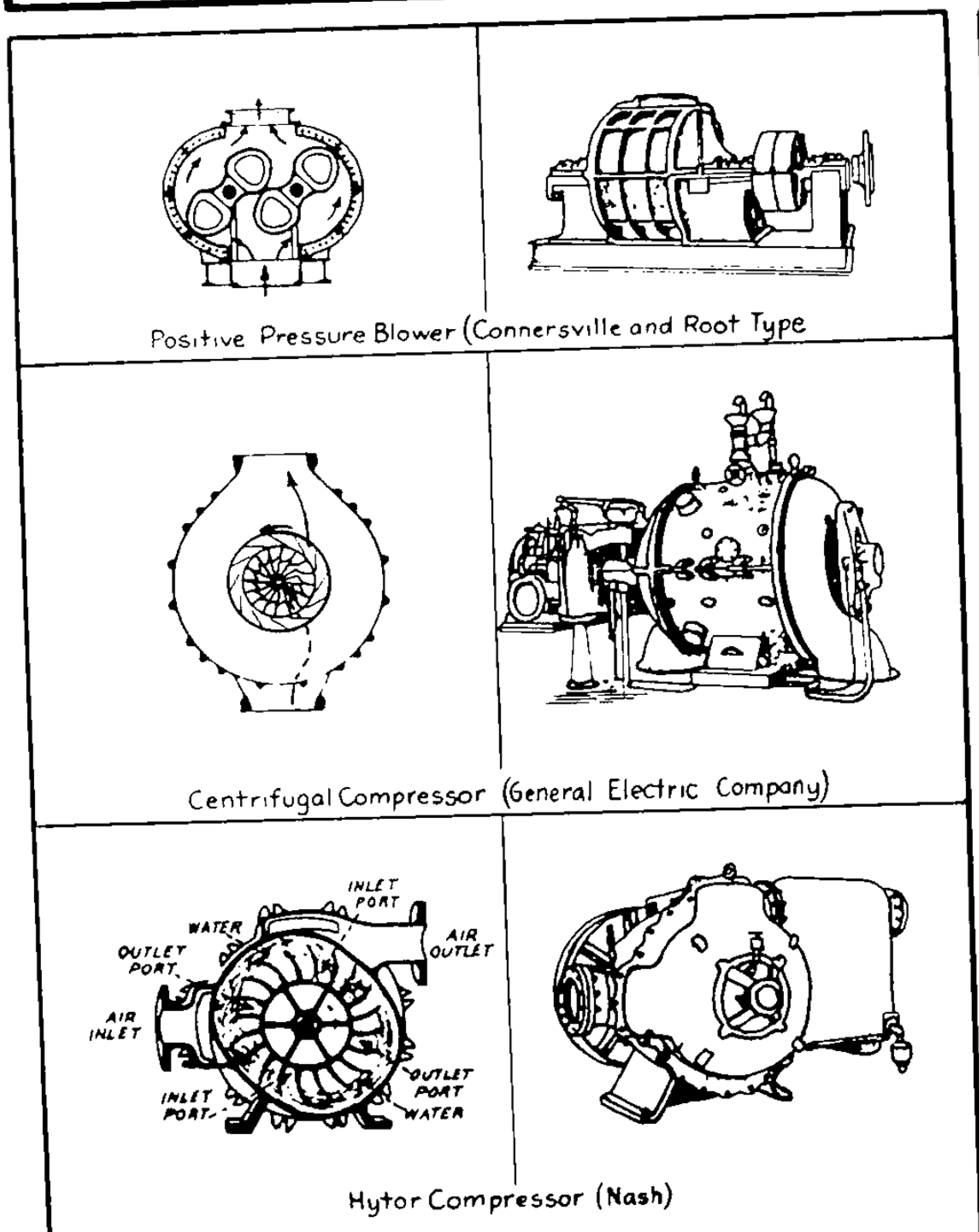
SEWAGE TREATMENT - ACTIVATED SLUDGE-2

TABLE A - BASIS OF DESIGN.

SYSTEM OF AERATION.	RECOMMENDED USE.	SEDIMENTATION TANKS DETENTION PERIODS.	DIFFUSED AIR.	AERATION TANKS.	ACTIVATED SLUDGE RETURN.	POWER CONSUMPTION.
Mechanically operated systems.	For flows up to 1 m.g.d.	Primary 30 to 60 min. Final 2 hours.	None	15' to 30' wide, 7' to 17' deep. Detention period 8 hrs. min. gross capacity based on daily flow + 25% for return activated sludge.	25% except where sludge thickeners are used.	11 to 14 kw. per m.g. of sewage. .25 to .75 kw. per lb. of B.O.D. removed
Air diffusion spiral flow system.	For flows over 1 m.g.d.	Same as above.	1 Cu. ft. per gal. introduced thru diffuser plates or tubes 5 to 10 lbs. per sq. in pressure.	15' to 30' wide 9.6' to 15' deep. Detention period 6 hrs. min. gross capacity based on daily flow + 25% for return activated sludge.	Same as above.	Same as above.

Detention periods, quantity of air supplied and activated sludge return are minimum design requirements of New York State, Dept. of Health. After plants are in operation a reduction in air supply and sludge return may produce a satisfactory effluent. Deeper tanks and larger quantities of air for longer periods will produce higher quality effluents.

Keefer* shows following normal variations in U.S. - air used cu. ft. per gal. of sewage .35 (weak sewage) to 1.7 (strong sewage); aeration period 3 hrs. to 8.4 hrs. and sludge return 10.5% to 49.5%.



Positive Pressure Blower (Connersville and Root Type

Centrifugal Compressor (General Electric Company)

Hytor Compressor (Nash)

FIG. B - TYPES OF AIR COMPRESSORS

AIR FILTRATION

Under normal conditions air contains large quantities of dust and other impurities.

In order to prevent the clogging of diffuser plates, it is necessary to thoroughly clean the air before it enters the compressors. For this purpose cloth filters, air washers, or oil cleaners are used. Canton flannel and 10 or 20 oz. duck may be employed for cloth filters. The allowable rate of filtration thru such media is about 4 cubic feet of air per sq. ft. of cloth per minute. Air washers intercept the dust and other floating particles by means of jets of water sprayed through the air. In oil cleaners a light oil is applied to a metallic medium. This arrangement, which causes a tortuous passage, removes the dust by retaining on the oily surfaces.

SLUDGE THICKENERS

Small mechanically cleaned sedimentation units frequently used to thicken sludge. A detention period of 12 hours will reduce water content of activated sludge from 99% to 95%. This reduction will decrease the required volume of digestion tanks.

* Keefer, Sewage Treatment Works, McGraw-Hill.

SEWAGE TREATMENT - ACTIVATED SLUDGE-3

FLOW OF AIR IN PIPES

$$P = \frac{1.268\, t\, Q^{1.852}}{1{,}000{,}000\, p\, d^{4.973}}$$ FRITZSCHE FORMULA

P = drop in pressure in pounds per square inch per foot of pipe
t = absolute temperature in degrees Fahrenheit = recorded temp in degrees F + 459.6
Q = cubic feet of free air per minute at 60 degrees Fahrenheit
p = absolute pressure in pounds per square inch = gage pressure + 14.7
d = diameter of the pipe in inches.

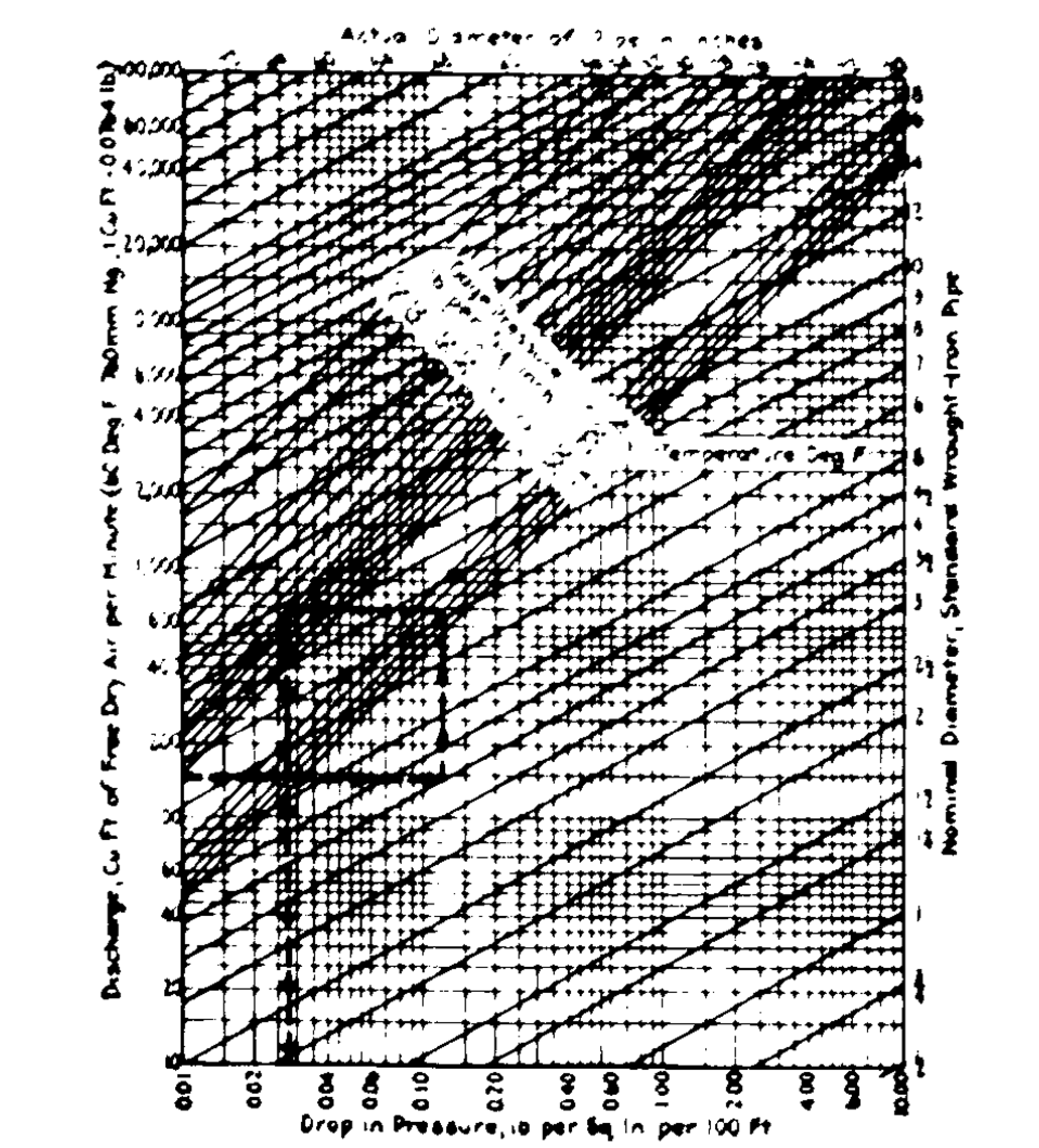


FIG. A - FLOW OF AIR IN CIRCULAR PIPES. MORRILL'S CHART. BASED ON FRITZSCHE FORMULA*

TABLE B - ECONOMICAL MAXIMUM VELOCITIES OF AIR FLOW IN PIPES.

SIZE OF PIPE INCHES	MAXIMUM VELOCITY FEET PER SEC	SIZE OF PIPE INCHES	MAXIMUM VELOCITY FEET PER SEC
6	20	16	50
8	28	20	54
10	35	24	57
12	41	30	60
14	46	36	62

TABLE C - POWER REQUIRED FOR COMPRESSING AIR.*

FINAL PRESSURE OF AIR LB. PER SQ. INCH	THEORETICAL WORK TO COMPRESS 1 MIL CU FT. OF FREE AIR HP - HR	FINAL PRESSURE OF AIR LB. PER SQ. INCH	THEORETICAL WORK TO COMPRESS 1 MIL CU FT OF FREE AIR HP - HR
1	72.3	8	490.2
2	144.0	10	596.5
3	200.8	12	697.1
4	265.2	14	785.4
6	384.7	16	875.9

TABLE D - RESISTANCE TO FLOW OF AIR THROUGH FITTINGS.

DIAMETER OF PIPE IN INCHES	EQUIVALENT LENGTH OF STRAIGHT PIPE IN FEET				
	GATE VALVE	ANGLE VALVE	LONG RADIUS ELBOW	STANDARD ELBOW	SIDE OUTLET TEE
2	1.3	4.8	1.7	3.6	7.1
3	2.1	7.7	2.8	5.7	11.4
4	3.0	10.7	3.9	7.9	15.8
6	4.8	17.4	6.4	12.9	25.6
8	6.7	24.1	8.9	17.9	35.6
10	8.8	31.5	11.5	23.4	46.6
12	10.9	39.3	14.4	29.3	58.6
16	15.4	55.4	20.3	41.3	82.6
20	20.2	72.7	26.6	54.1	108.2
24	25.1	90.4	33.1	67.3	134.6
30	32.8	118.1	43.3	87.9	175.8
36	40.9	147.2	54.0	109.6	219.2
42	49.2	177.1	64.9	131.9	263.8
48	57.7	207.7	76.2	154.6	309.2

*Data from Metcalf & Eddy, American Sewerage Practice, McGraw Hill

SEWAGE TREATMENT–SLUDGE DIGESTION & DRYING

TABLE A-SLUDGE PRODUCTION & REQUIRED DIGESTION TANK CAPACITIES.

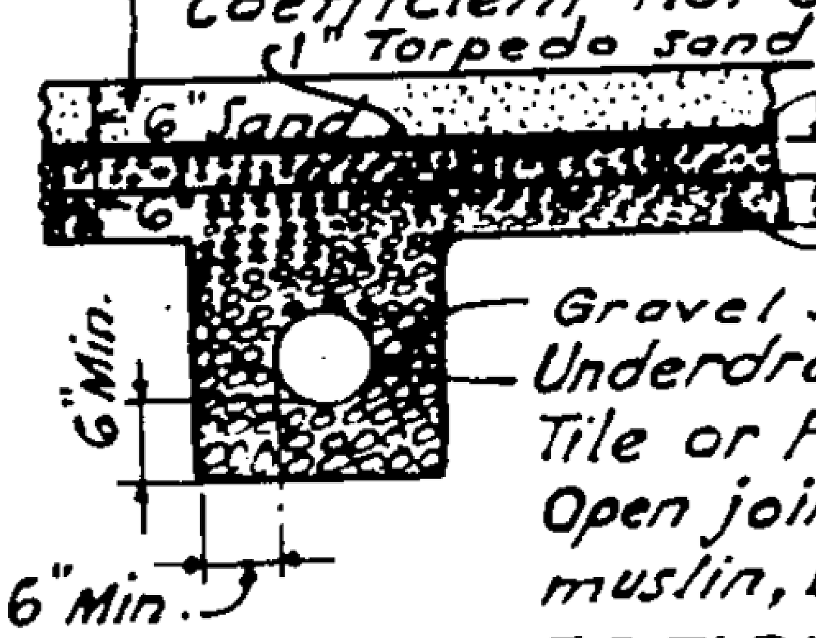
TYPE OF SEWAGE TREATMENT PLANT.	GALLONS OF SLUDGE PRODUCED PER MILLION GALLONS OF SEWAGE.*	DIGESTION TANK CAPACITY CUBIC FEET PER CAPITA. HEATED	DIGESTION TANK CAPACITY CUBIC FEET PER CAPITA. UNHEATED
Plain sedimentation	3000	2.0	3.0
Standard (low capacity) trickling filter	700	2.5-3.0	4.0-4.5
High capacity trickling filter	4000-6000 **	2.5-3.0	4.0-4.5
Plain sedimentation with chemical precipitation	5100	3.0	4.5
Activated sludge	19,400	3.5-4.0	5.0-6.0

GAS PRODUCTION IN DIGESTION TANKS: The gas which results from the processes of sludge digestion amounts to from 8 to 11 Cu. ft. per pound of organic solids added to the digestion tanks and 0.3 to 1.0 Cu. ft. a day per capita served. The gas has a nominal heating value of 500 to 800 B.t.u. per cu. ft. Digested sludge as drawn from tanks commonly has a moisture content of 90 to 95%.

TABLE B-SIZE OF SLUDGE BEDS.

TYPE OF SLUDGE	NO. OF SQ. FT. PER CAPITA.
Imhoff tank sludge	1.0 - 1.5
Separate sludge digestion	1.5 - 2.0
Activated sludge (digested)	2.0

For glass covered beds, use 50 to 65% of above values.



TYPICAL SECTION OF SLUDGE BED.

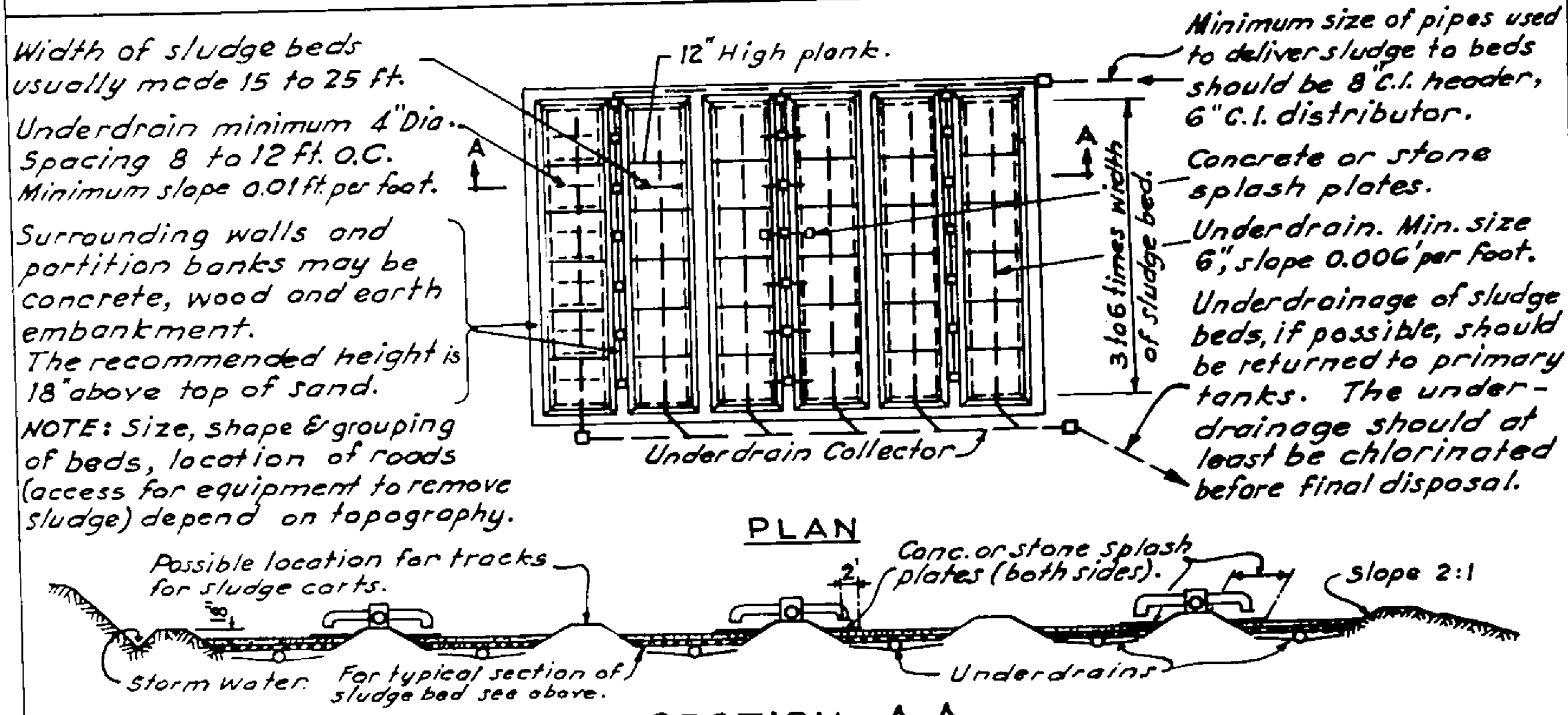


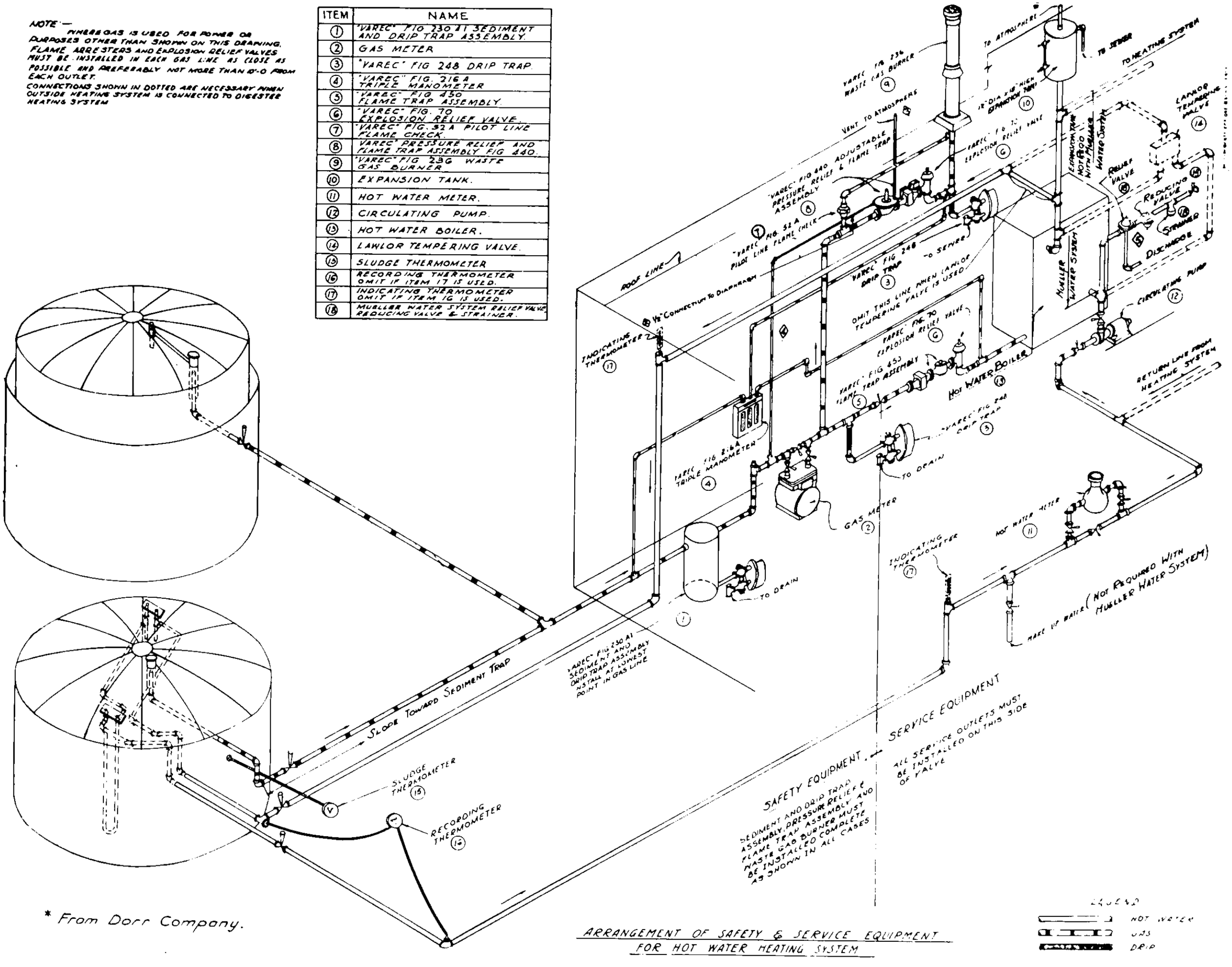
FIG. C - TYPICAL LAYOUT OF SLUDGE BEDS.

* Data from Metcalf & Eddy, American Sewerage Practice, Mc Graw-Hill ** From Dorr Co.
Manufacturers should be consulted for equipment for drying sludge by vacuum, etc.

SEWAGE TREATMENT - DIGESTER GAS & HOT WATER LAYOUT*

NOTE — WHERE GAS IS USED FOR POWER OR PURPOSES OTHER THAN SHOWN ON THIS DRAWING, FLAME ARRESTERS AND EXPLOSION RELIEF VALVES MUST BE INSTALLED IN EACH GAS LINE AS CLOSE AS POSSIBLE AND PREFERABLY NOT MORE THAN 10'-0 FROM EACH OUTLET.
CONNECTIONS SHOWN IN DOTTED ARE NECESSARY WHEN OUTSIDE HEATING SYSTEM IS CONNECTED TO DIGESTER HEATING SYSTEM

ITEM	NAME
1	"VAREC" FIG 230 A1 SEDIMENT AND DRIP TRAP ASSEMBLY.
2	GAS METER
3	"VAREC" FIG 248 DRIP TRAP.
4	"VAREC" FIG. 216 A TRIPLE MANOMETER
5	"VAREC" FIG 450 FLAME TRAP ASSEMBLY.
6	"VAREC" FIG. 70 EXPLOSION RELIEF VALVE.
7	"VAREC" FIG. 52 A PILOT LINE FLAME CHECK.
8	VAREC" PRESSURE RELIEF AND FLAME TRAP ASSEMBLY FIG 440.
9	"VAREC" FIG 236 WASTE GAS BURNER.
10	EXPANSION TANK.
11	HOT WATER METER.
12	CIRCULATING PUMP.
13	HOT WATER BOILER.
14	LAWLOR TEMPERING VALVE.
15	SLUDGE THERMOMETER
16	RECORDING THERMOMETER OMIT IF ITEM 17 IS USED.
17	INDICATING THERMOMETER OMIT IF ITEM 16 IS USED.
18	MUELLER WATER SYSTEM RELIEF VALVE REDUCING VALVE & STRAINER.



ARRANGEMENT OF SAFETY & SERVICE EQUIPMENT FOR HOT WATER HEATING SYSTEM

* From Dorr Company.

SEWAGE TREATMENT – CHLORINATION

TABLE A — CHLORINE DOSAGE BASED ON AVERAGE FLOW.*

TYPE OF EFFLUENT	PARTS PER MILLION P.P.M.	POUNDS PER MILLION GALLONS
Raw Sewage	20 - 25	166 - 208
Sedimentation tank effluent	15 - 20	125 - 166
Trickling filter effluent	12 - 15	100 - 125
Sand filter effluent	6 - 10	50 - 82
Activated sludge effluent	6 - 10	50 - 82

Pre-chlorination for odor control requires between 3 and 15 p.p.m. Chlorinators should be designed to have a maximum capacity which will satisfy the values listed in table above. 100% standby equipment should be provided.
For small installations hypochlorinators may be used economically.

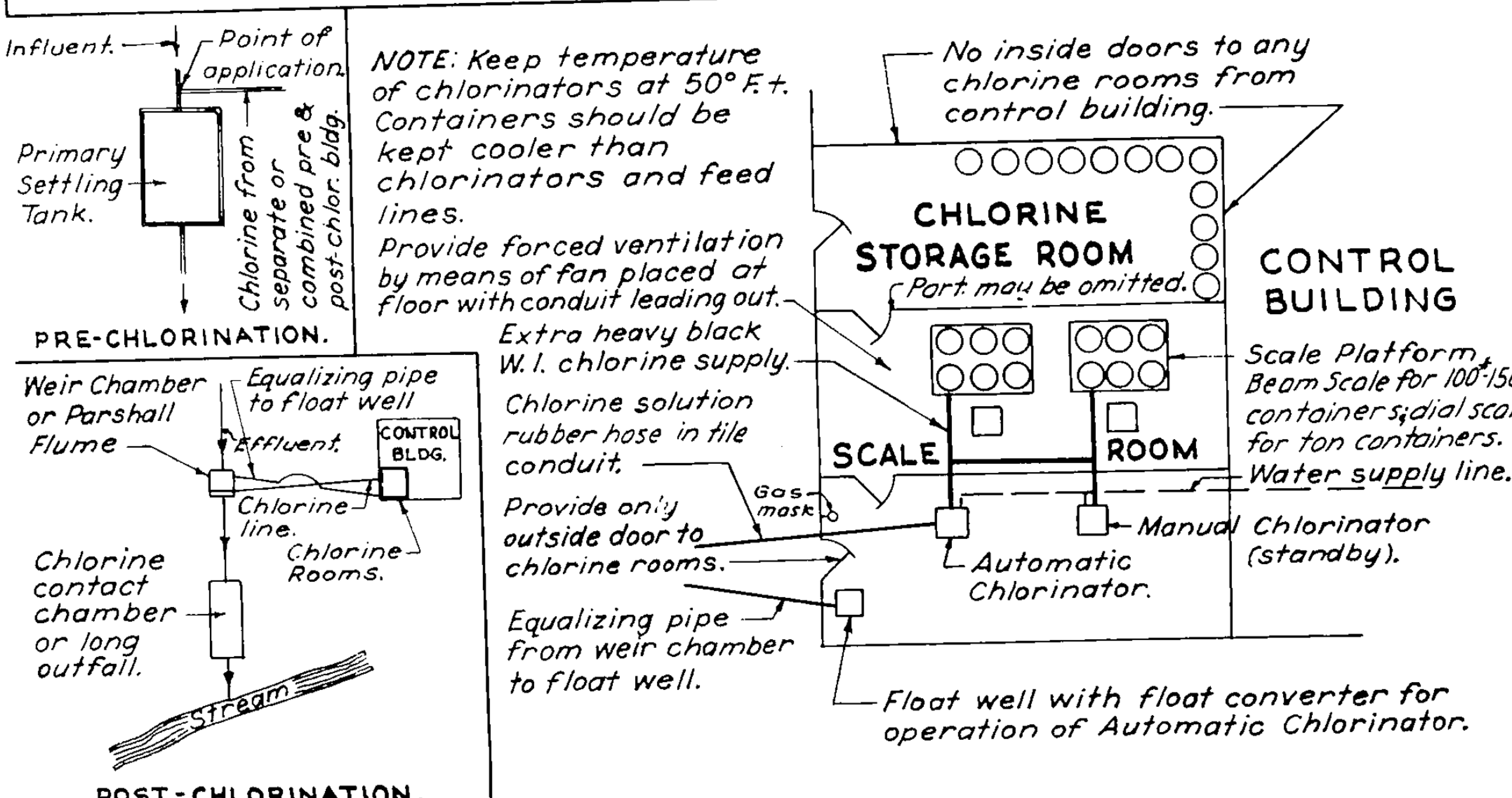


FIG. B— TYPICAL LAYOUT FOR CHLORINATOR INSTALLATION.

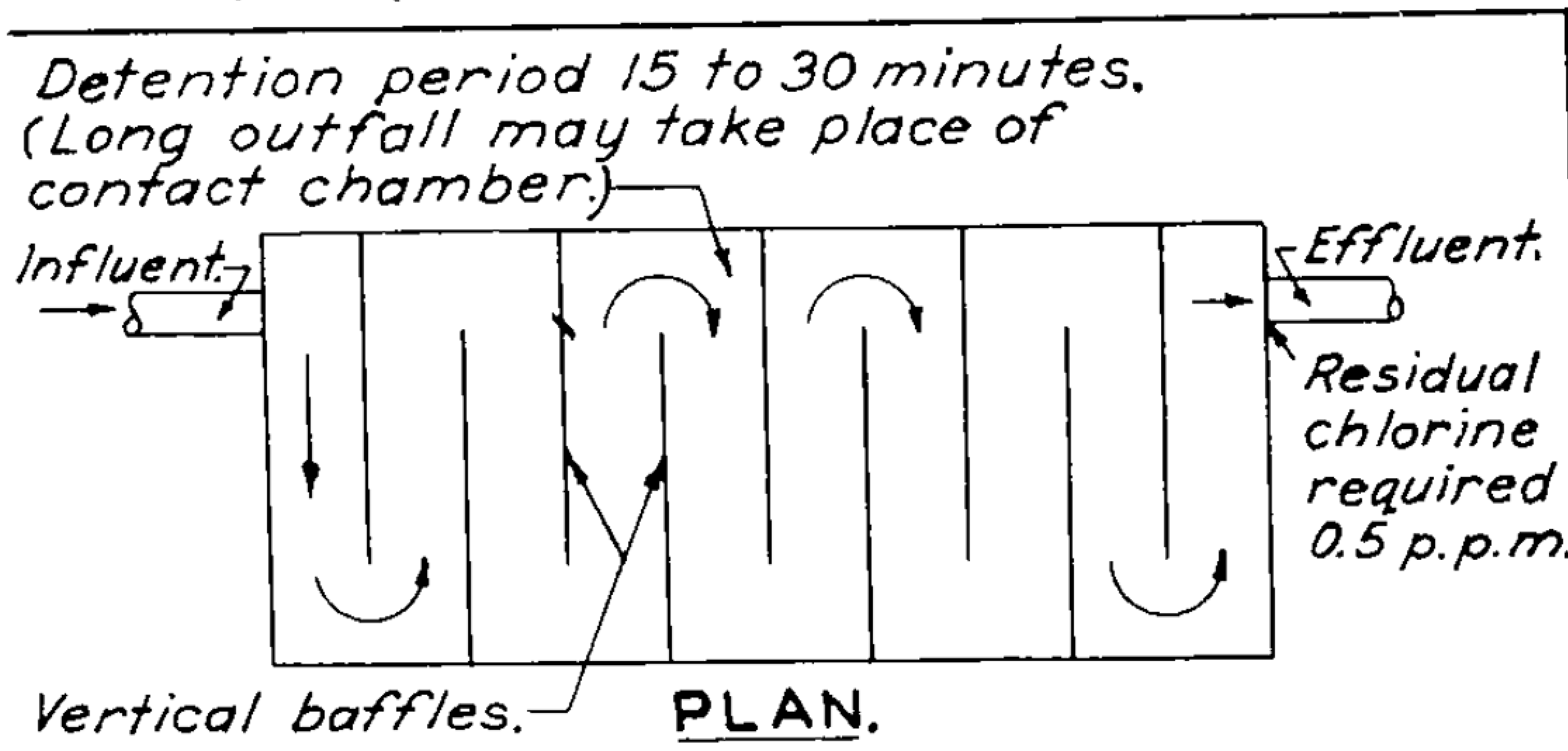


FIG. D — CONTACT CHAMBER.

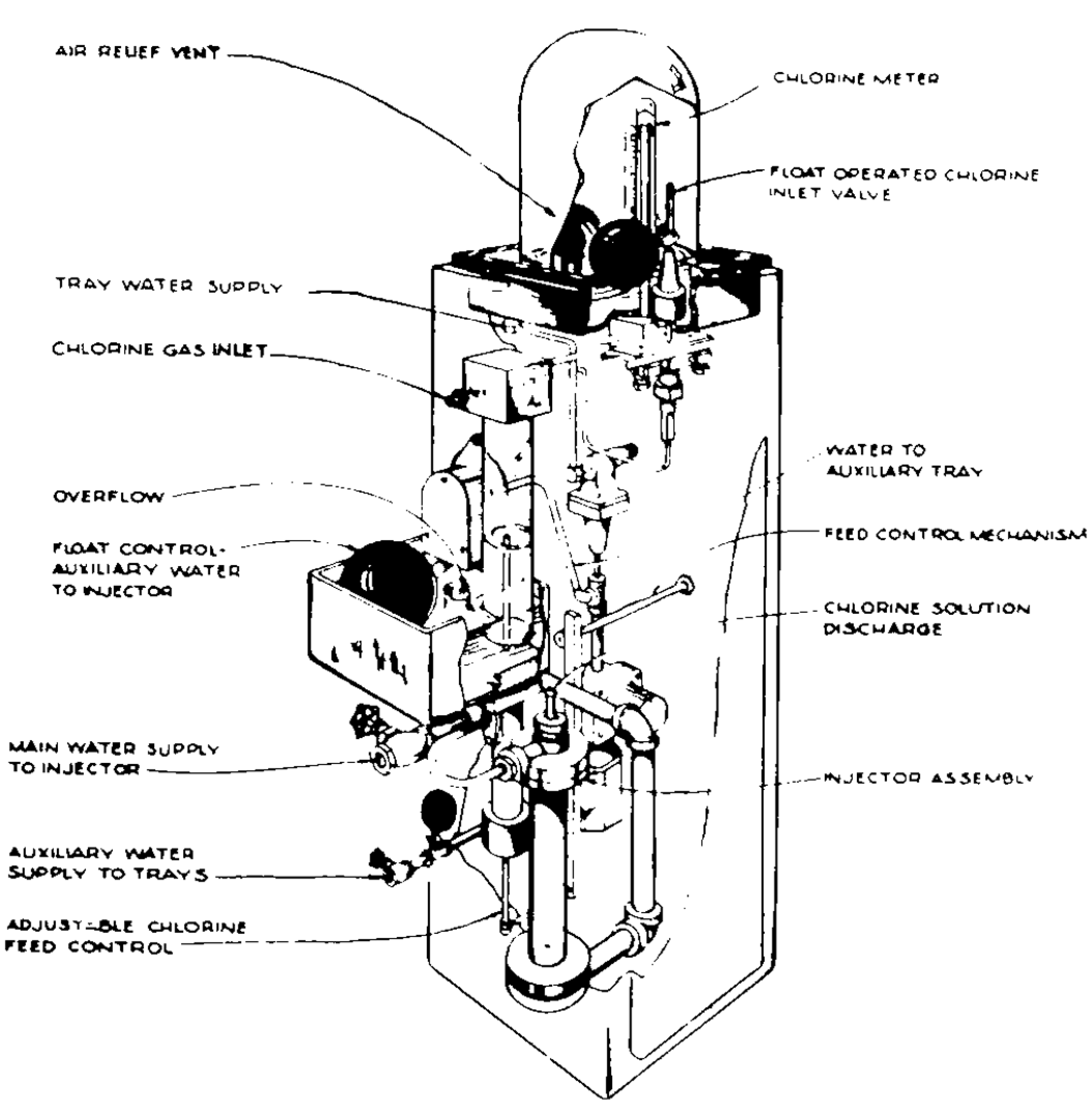
TABLE C — CHLORINE CYLINDER DATA.

NET WEIGHT	GROSS WEIGHT	DIAM.	LENGTH	MAX. RATE OF WITHDRAWAL
100 Lbs.	195 Lbs.	$8\frac{1}{2}$"	4'-6"	40# per 24 hrs.
150 Lbs.	280 Lbs.	$10\frac{1}{2}$"	4'-6"	40# per 24 hrs.
1 Ton	3500 Lbs.	30"	6'-$9\frac{1}{2}$"	450# per 24 hrs.

Chlorine also comes in tank cars.

*Compiled from various State Board of Health laws.

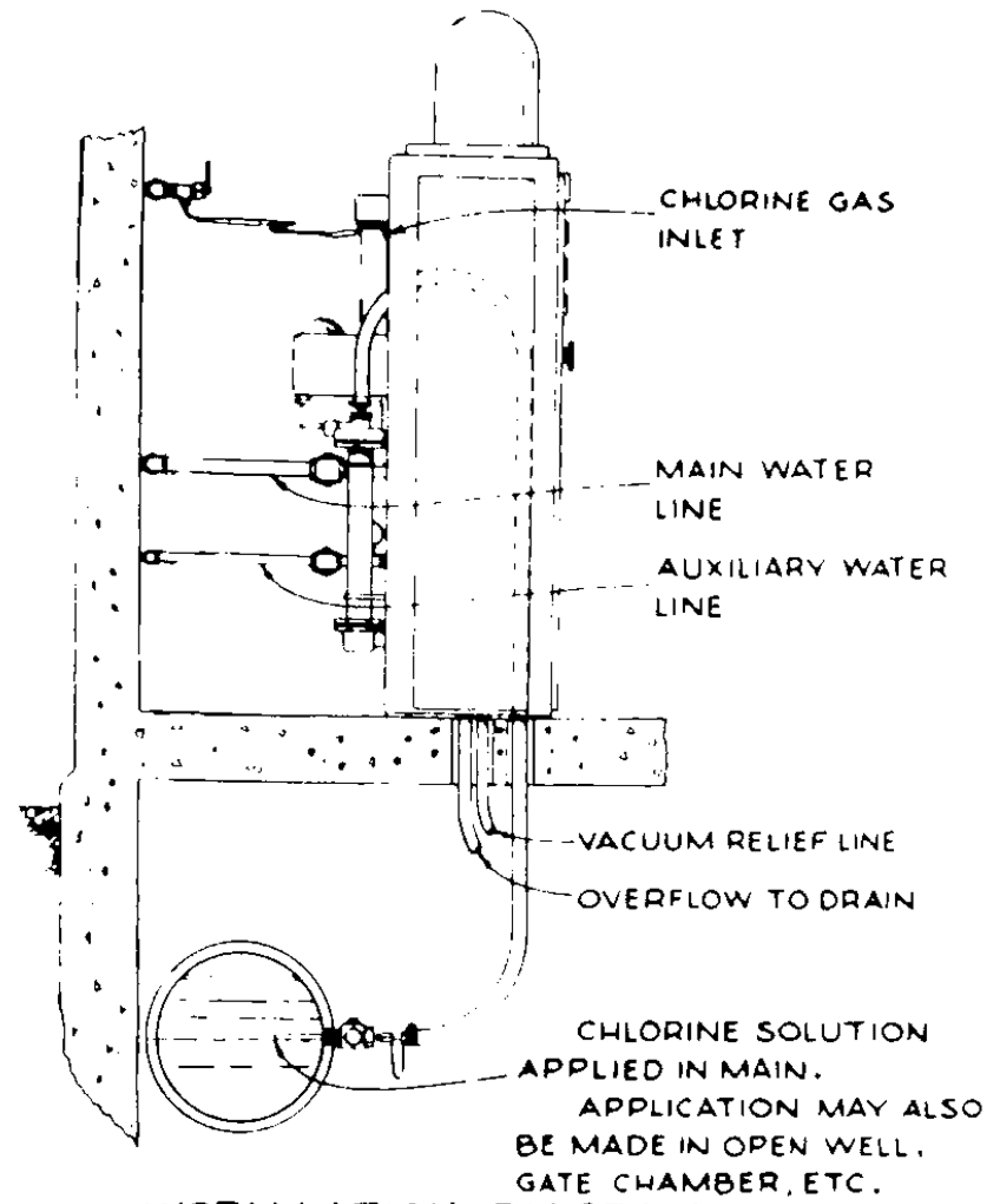
SEWAGE TREATMENT - CHLORINATORS & HYPOCHLORINATORS



MANUALLY OPERATED CHLORINE CONTROL APPARATUS*

Chlorinators are available both manually and automatically operated. They are supplied for a great variety of ranges.

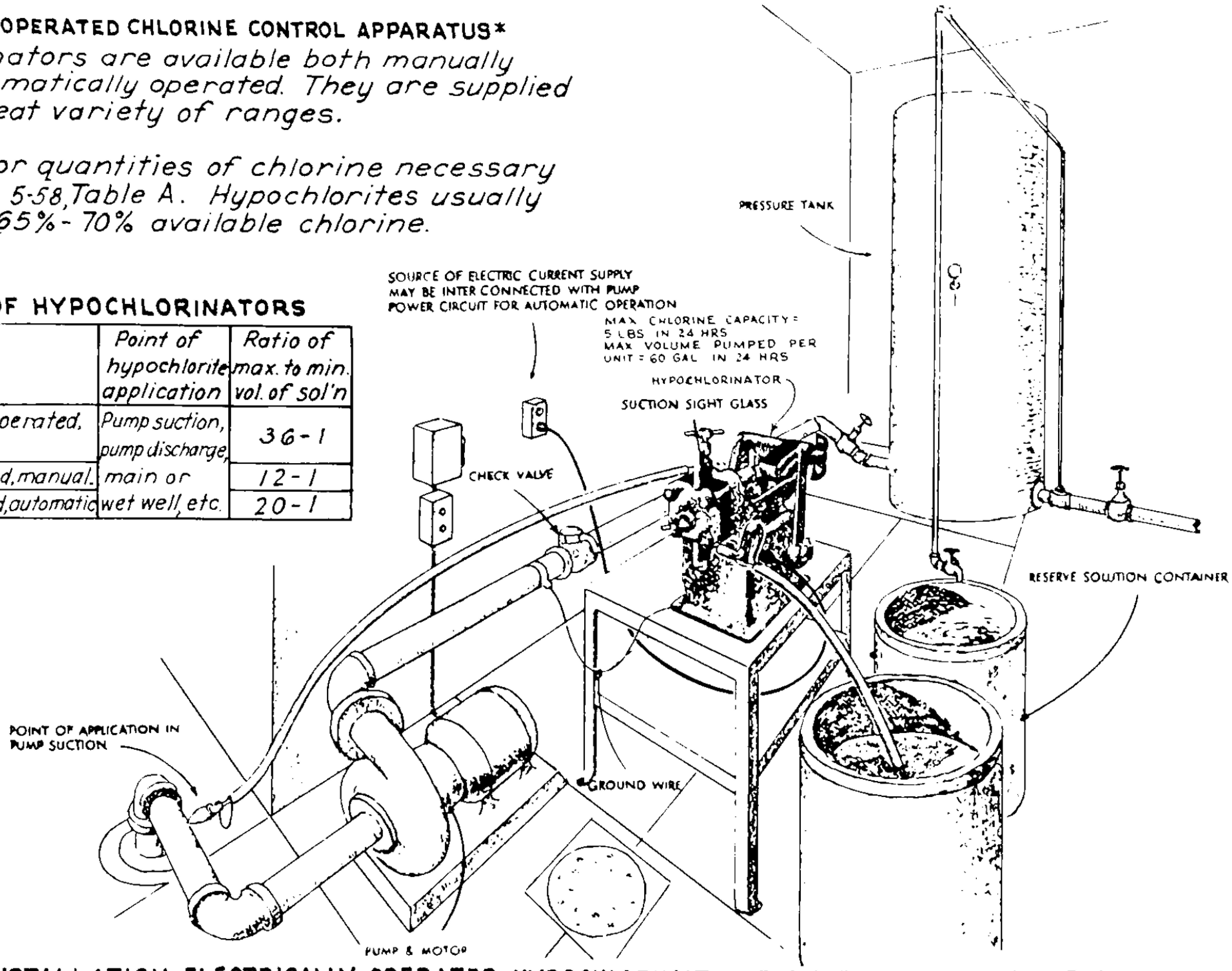
NOTE: For quantities of chlorine necessary see page 5-58, Table A. Hypochlorites usually contain 65%-70% available chlorine.



INSTALLATION DIAGRAM
MANUALLY OPERATED CHLORINE CONTROL APPARATUS*

RANGES OF HYPOCHLORINATORS

Type	Point of hypochlorite application	Ratio of max. to min. vol. of sol'n
Electrically operated, manual.	Pump suction, pump discharge,	36-1
Water operated, manual.	main or	12-1
Water operated, automatic	wet well, etc.	20-1



TYPICAL INSTALLATION-ELECTRICALLY OPERATED HYPOCHLORINATOR FOR APPLICATION IN PUMP SUCTION*

For sewage treatment-pump, motor and pressure tank generally not required.

** From Wallace & Tiernan Co., Inc.*

SEWAGE TREATMENT-CLASSIFICATION OF RECEIVING WATERS

TABLE A *

CLASSIFICATION OF RECEIVING WATERS ACCORDING TO USE AND REQUISITE QUALITY

Class	Use	Standards of Quality at Low-water Stage	Required Treatment of Sewage	Emergency Treatment
(1)	(2)	(3)	(4)	(5)
D (Bad)	For rough industrial uses and for irrigation	Absence of nuisance, odors and unsightly suspended or floating matters dissolved oxygen present	Sedimentation, except in large receiving waters	Chlorination ferric chloride treatment to remove hydrogen sulphide addition of nitrate to supply oxygen
C	For fishing	Dissolved oxygen content not less than 3 and preferably 5 p.p.m. CO_2 not more than 40 and preferably 20 p.p.m.*	Sedimentation chemical or biological treatment where necessary	Aeration addition of diluting waters
B	For bathing, recreation, and shellfish culture	No visible sewage matters A bacterial standard such as *B. coli* less than 100 per 100 ml	As in class *C*, chlorination if necessary	Chlorination
A (Good)	For drinking water after chlorination	In the absence of filtration† a bacterial standard such as *B. coli* less than 50 per 100 ml. Chemical standards for substances not removable by common treatment methods	As in class *B*, removal of certain taste-producing substances such as phenols	Treatment of drinking water with heavy doses of chlorine and with activated carbon

* At high temperatures the tolerance of fish to low D.O. and high CO_2 is decreased; high temperatures are also objectionable in themselves.

† With complete purification in modern filtration works, a bacterial standard such as 5,000 *B. coli* per 100 ml. will normally permit production of a safe drinking water.

TABLE B

INTERSTATE COMPACT REQUIREMENTS OF CONNECTICUT, NEW YORK, AND NEW JERSEY FOR TREATMENT OF SEWAGE DISCHARGED INTO THEIR TIDAL WATERS

	Class *A* Waters expected to be used primarily for recreational purposes, shellfish culture, and development of fish life	Class *B* All other waters
1. Floating solids	Full removal	Full removal
2. Suspended solids	60% removal	10% removal or enough to avoid sludge deposits
3. Coliform bacteria in water samples during bathing season	Probable number of not more than 1 per c.c. in 50% of 1-c.c. samples	
4. Dissolved oxygen saturation in vicinity of outfall	Not less than 50% during any week of the year	Not less than 30%

NOTES: 1. See Page 5-40, Table D, Dilution Requirements.

2. No National Standards governing the discharge of sewage and sewage effluents into receiving waters have yet been evolved in the United States. Various State and Interstate Commissions have established standards for waters under their jurisdiction (See Table C below).

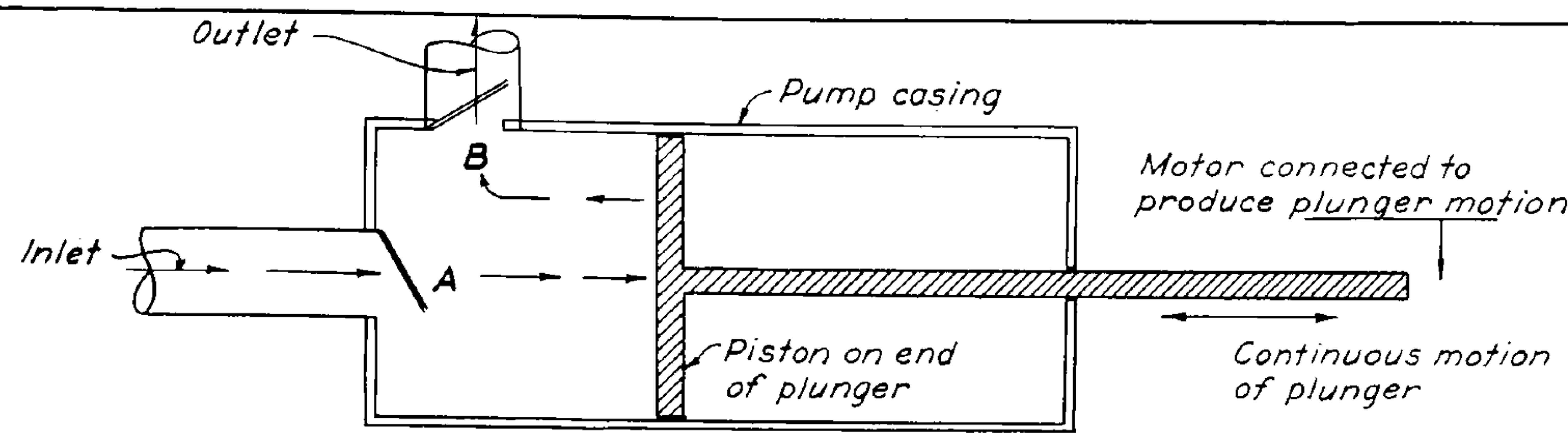
3. Column 5, Table A, at left indicates certain treatment measures to be applied in emergencies, such as shut down or overloading of treatment works, extreme low water or hot weather and the emergency use of the receiving water for other than customary purposes.

4. Ordinarily it is permissible to discharge the water-carried wastes from isolated dwellings and small communities without treatment into receiving waters of Class C or D. Sometimes Primary Treatment is required.

5. For more Analytical methods for determining allowable loading of receiving waters with sewage see "Sewage Treatment" by Imhoff & Fair.

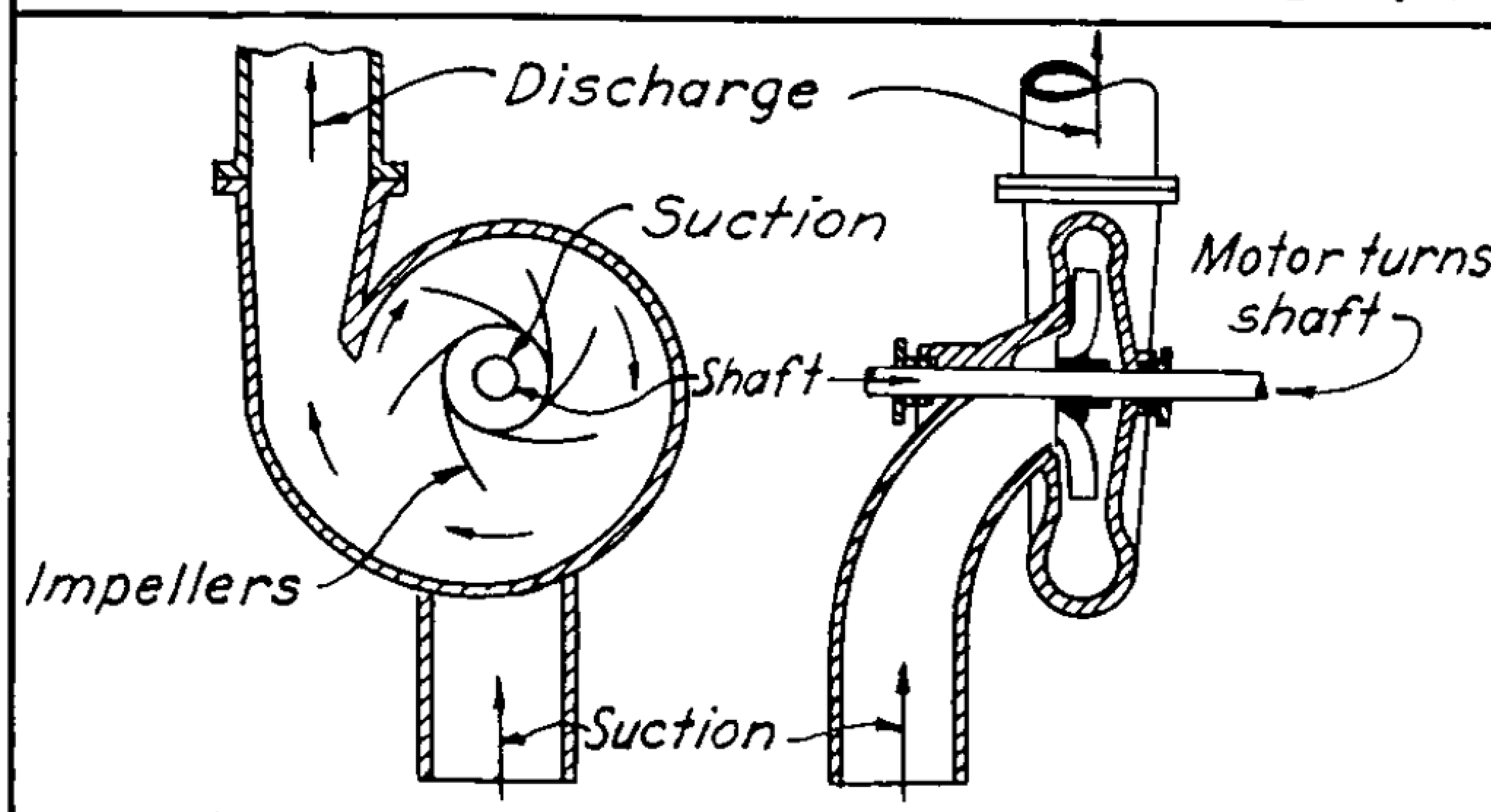
* Data from Sewage Treatment by Imhoff & Fair.

SEWAGE TREATMENT-PUMP TYPES & COMMINUTORS



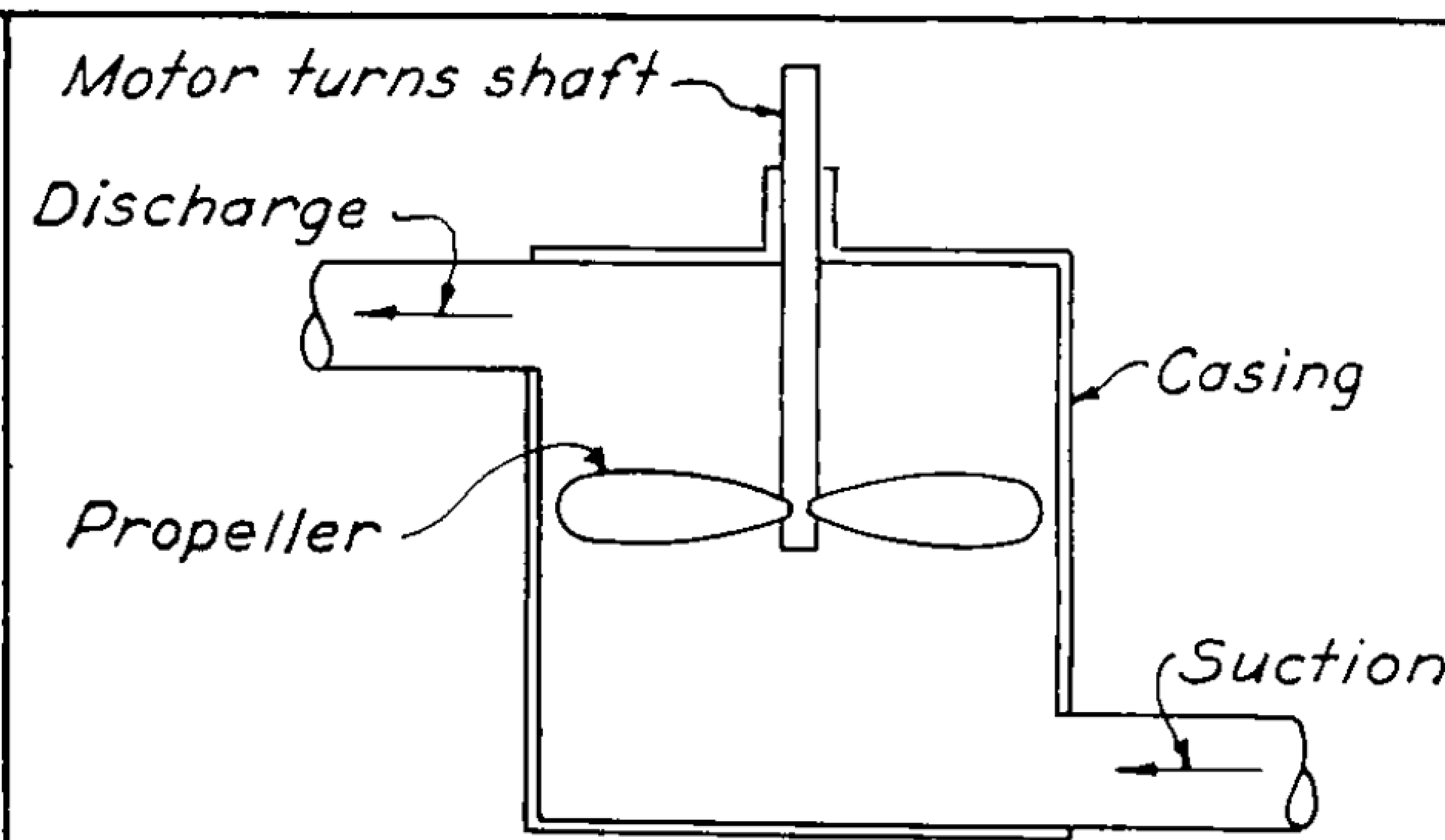
Plunger moves to right; Valve A open, Valve B closed; water enters from inlet pipe. Plunger moves to left; Valve A closes, Valve B opens; water is expelled through outlet pipe.

FIG. A. PLUNGER TYPE.



Turning of impellers throws water at high velocity against outside casing and water leaves through discharge. Low suction pressure at center causes outside water under atmospheric pressure to enter pump.

FIG. B. CENTRIFUGAL TYPE.



Turning of propeller causes vertical upward reaction on water in casing, forcing it to rise.

FIG. C. PROPELLER TYPE.

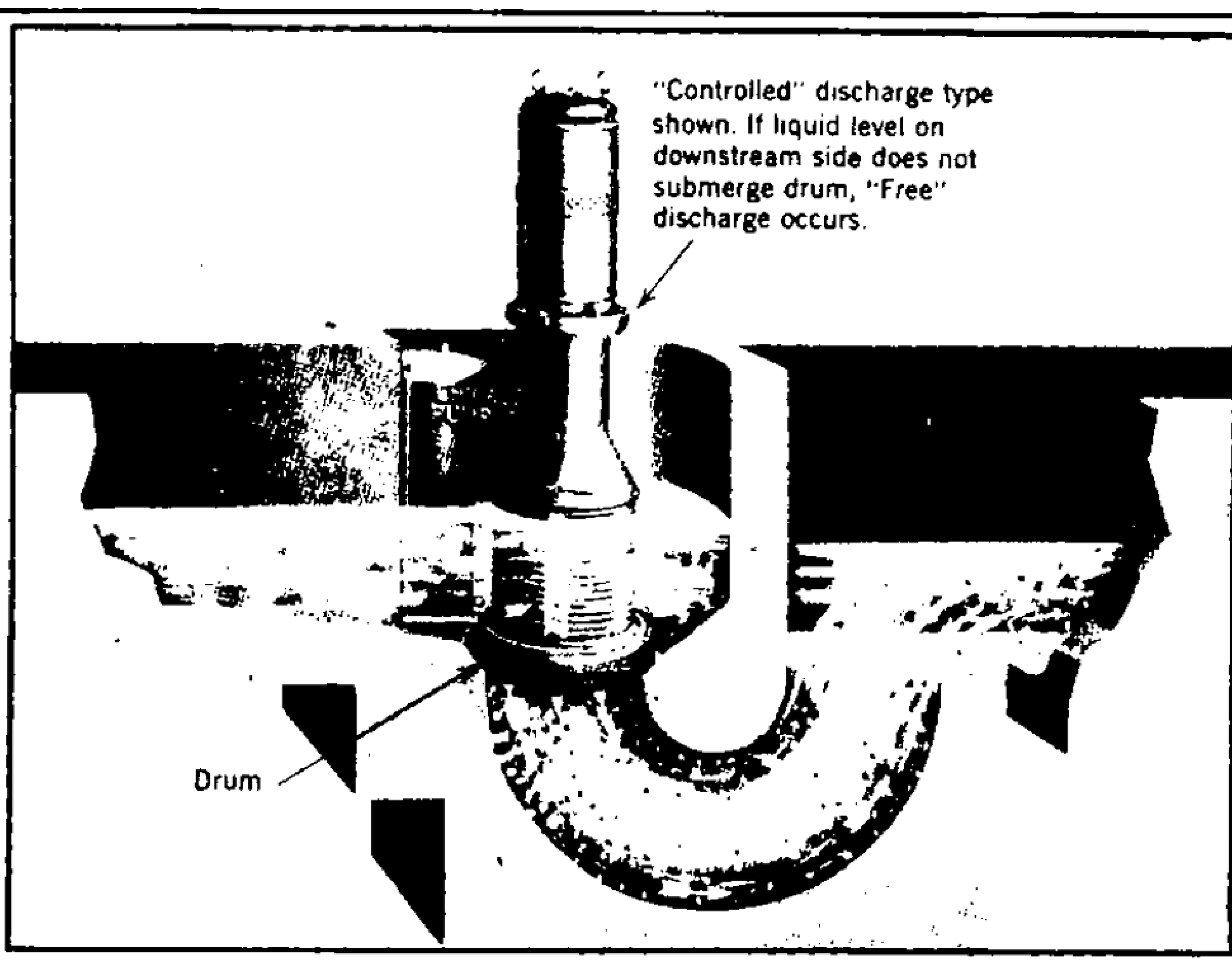


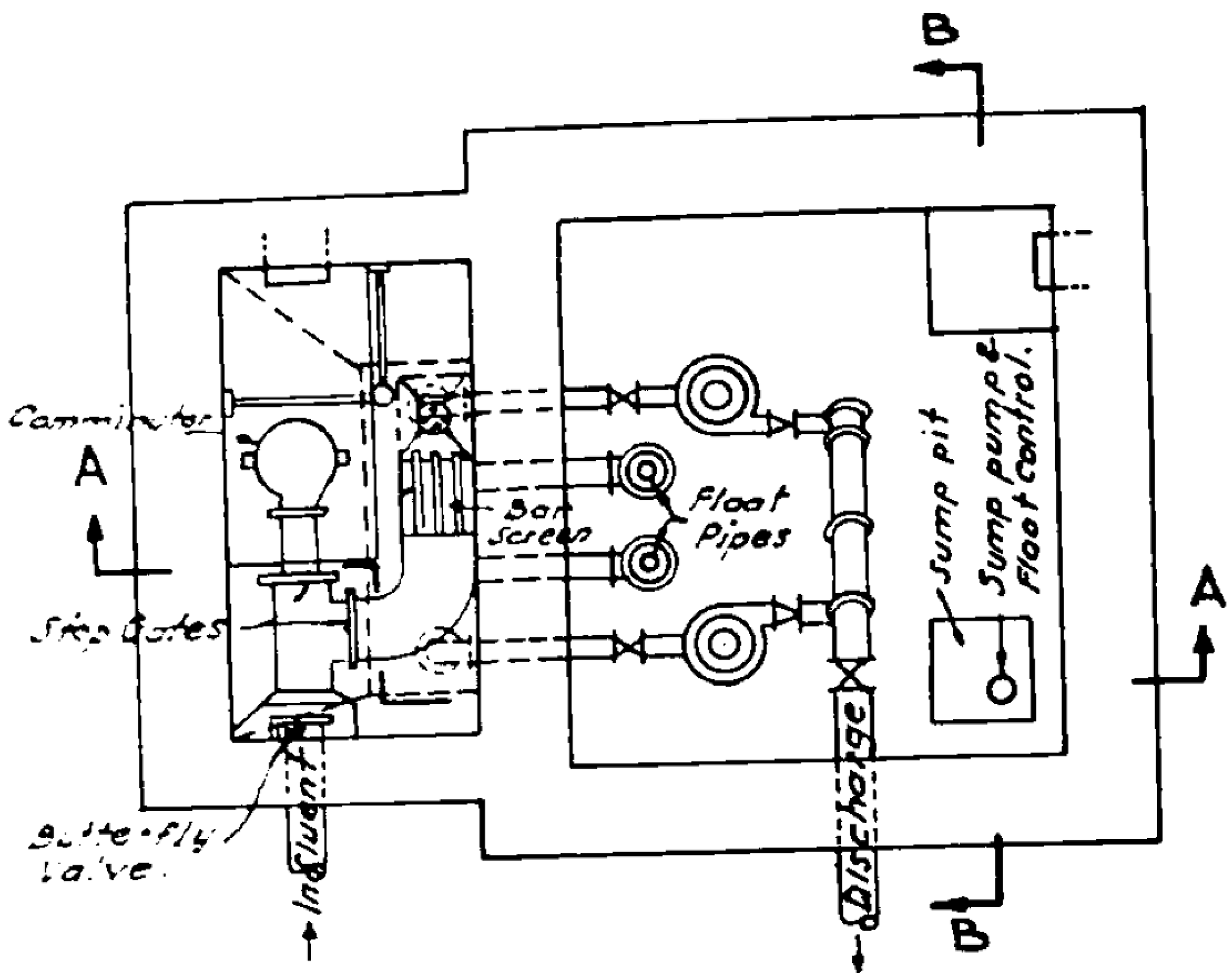
FIG. D. COMMINUTOR*

TABLE E. COMMINUTOR SIZES & CAPACITIES.*

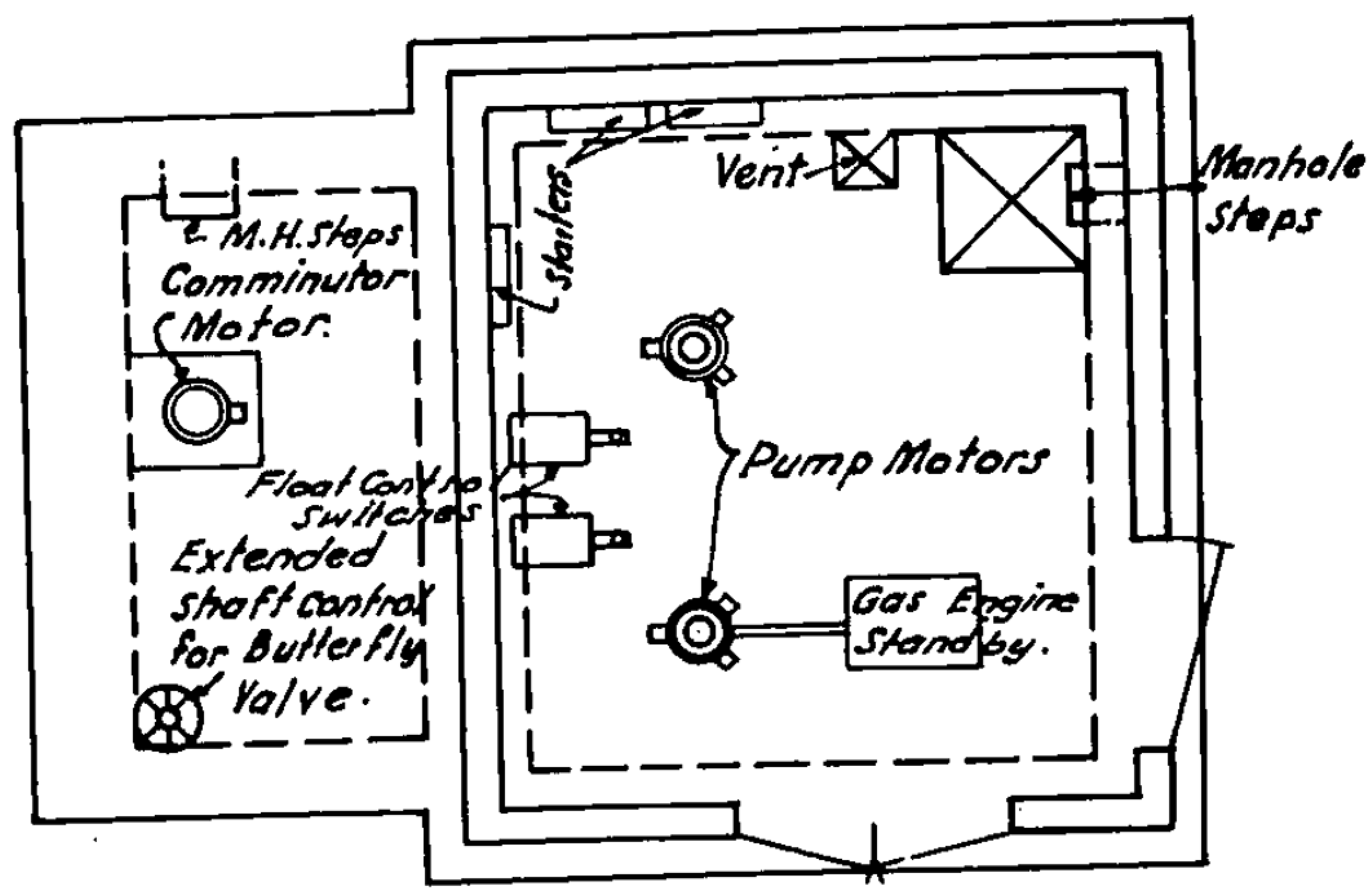
NUMBER	SIZE OF MOTORS	OVERALL CAPACITIES CONTROLLED DISCHARGE M.G.D.	OVERALL CAPACITIES FREE DISCHARGE M.G.D.
7 A	1/4 H. P.	.0 to .35	.0 to .30
10 A	1/2 H. P.	.17 to 1.1	.17 to .82
15 M	3/4 H. P.	.4 to 2.3	.4 to 1.4
25 M	1 1/2 H. P.	1.0 to 6.0	1.0 to 3.6
25 A	1 1/2 H. P.	1.0 to 11.0	1.0 to 6.5
36 A	2 H. P.	1.5 to 25.0	1.5 to 9.6
54 A	Separately designed for each job.		

* From Chicago Pump Co.

SEWAGE TREATMENT – TYPICAL SEWAGE LIFT STATION



PLAN OF COMMINUTOR & PUMP ROOM.

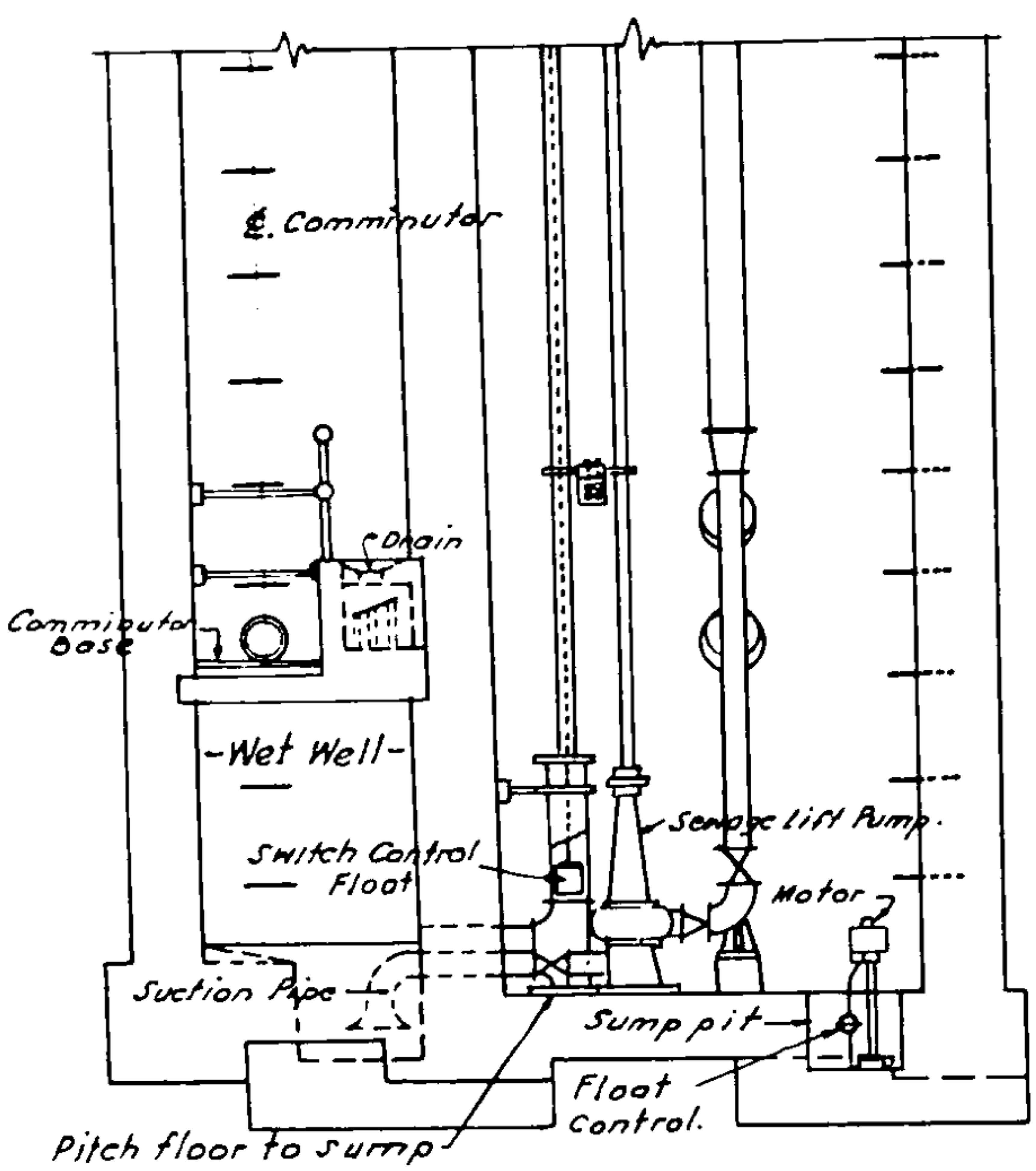


PLAN OF CONTROL ROOM.

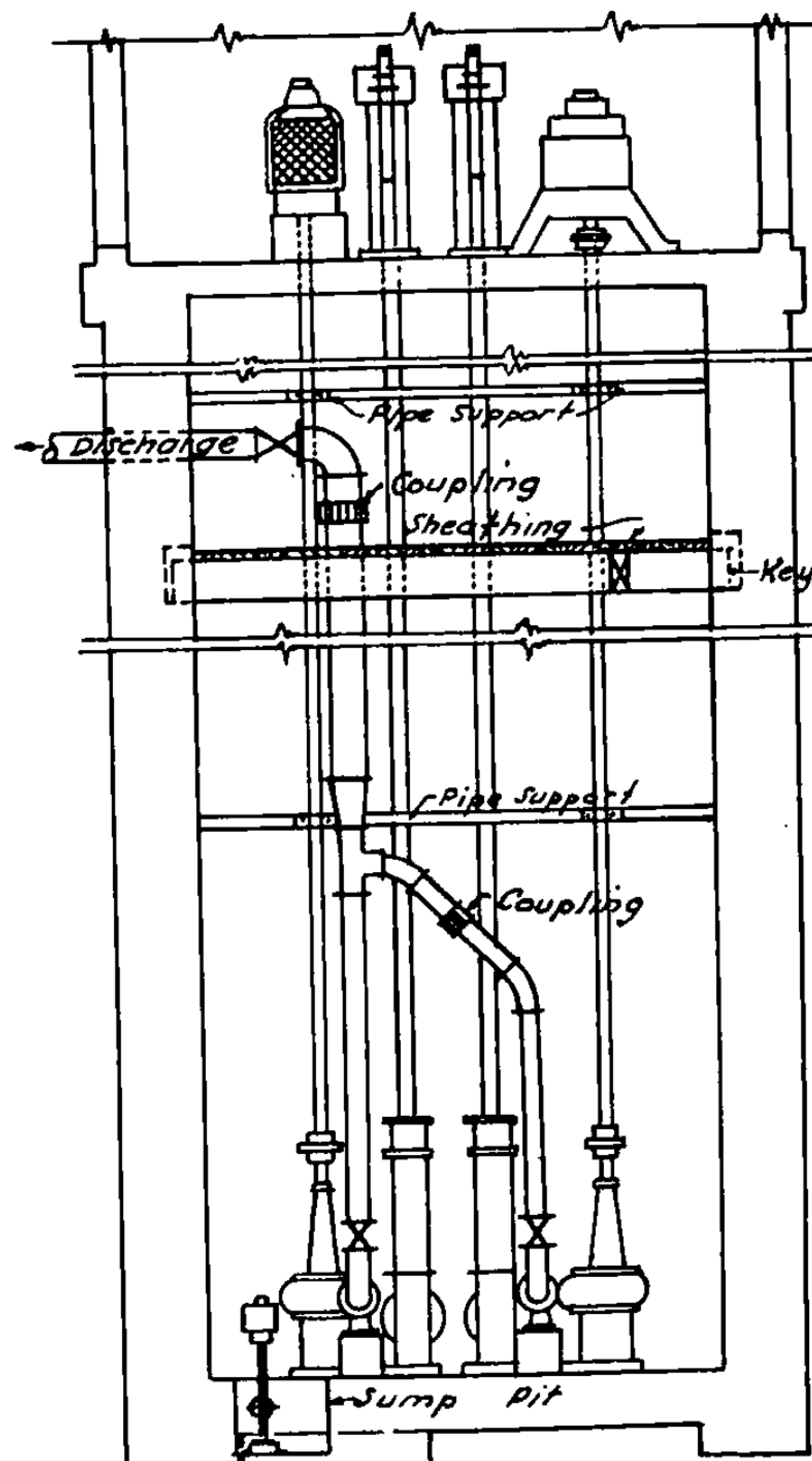
NOTES FOR DESIGN

For stations with two pumps.

Capacity of pump, each for maximum flow. Size of wet well. 15 minutes detention, average daily flow.



SECTION A-A



SECTION B-B

SEWAGE TREATMENT — SMALL SYSTEMS*

HOUSE SEWER

LENGTH. *Make 50'-0" to 100'-0" long, run as directly as possible. If over 300'-0" long place Manhole at center. Longer runs are desirable.*

MATERIAL: *Salt glazed clay bell and spigot tile pipe or cement bell & spigot (cast iron is excellent but expensive). If near well or any water supply use cast iron.*
Where trees or shrubs may cause root stoppage in clay pipe use cast iron.
Use 5'0" to 6'0" of Cast Iron pipe where leaving building.
Use cement joints for clay pipe, lead for cast iron.

SIZE. *4" for small installation, but 6" is better in all cases.*

DEPTH = *In Northern latitudes start sewer approximately 1'-6" below gd surf. In Southern latitudes start may be just below ground surface.*

SLOPE = *Slope 4" sewer 1/5" per foot minimum (equivalent to 2" in 10'-0"). Slope 6" sewer 1/10" per foot minimum (equivalent to 1" in 10'-0").*

SEPTIC TANK

EFFLUENT SEWER

LENGTH. *10'0" for small system, for large systems allow 40'0" to 50'0" min.*

MATERIAL: *Same as for house sewer.*

SIZE. *4" unless very large system.*

SLOPE = *1/20" to the foot minimum (equivalent to 1/2" in 10'0").*
Slope should be uniform.

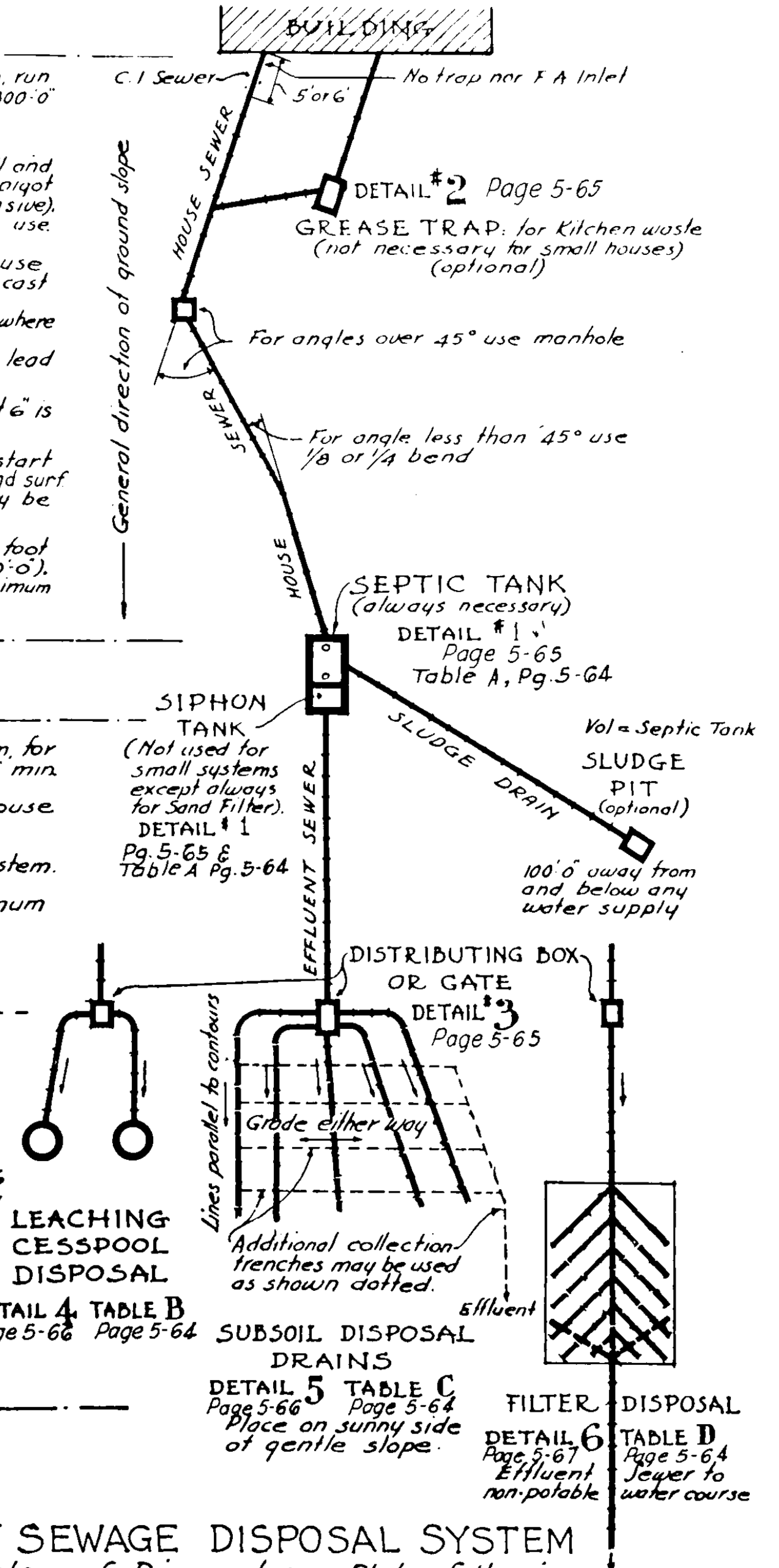
DISTRIBUTION FIELD

(Absorption field) for disposal of Effluent or filtering of Effluent.

Slope for closed joints 5" per 100 lin. ft.
Slope for open joints 3" to 4" per 100 lin. ft.

DISPOSAL METHODS
3 POSSIBLE TYPES.
For details see {*Details 4.5.6* / *Pages 5-66, 5-67*}

See Tables B, C, D. Pg. 5-64.



KEY DIAGRAM *of* SEWAGE DISPOSAL SYSTEM

For selection of System of Disposal see Plates following.

Checked by Ralph Eberlin, C.E.

**Adapted from Architectural Graphic Standards by Ramsey & Sleeper.*

SEWAGE TREATMENT—SMALL SYSTEMS*—DATA

CRITERIA for SELECTION of TYPE of DISTRIBUTION of the EFFLUENT

	LEACHING CESSPOOL (one or more may be used as needed)	SUBSOIL DISPOSAL DRAINS Type 5.1 includes, in addition, collection tile under the distributing tile.	SAND FILTER Rectangular, circular or narrow trench types. Open or closed type.
TERRAIN SLOPE OR GRADE	Applicable to any slope	For level or slight slope	Applicable to any slope, except filter area to be approximately level.
POROSITY OF SOIL	Soil adjacent to cesspools must be fairly porous below intake. Above may be impervious	Top 1'-6" to 2'-0" must be fairly porous unless type 5.1 is used, and this may be used with impervious soil	Soil may be impervious.
GROUND WATER	Water level must be at least 8' below grade at cesspools. Never less than 2'-0" below bottom of cesspools	Water level 2'-6" under grade at field. For type 5.1 4'-0"	Water level approximately 4'-0" below elev. of filter
ORIENTATION AND LOCATION	Not important. Small area required not less than 15'-0" from building	If possible place field on southern slope; drains run parallel to contours. Requires large area	Open type requires placing to leeward and away from buildings; on sunny site. Closed type requires more area than open. Small area required.
FINAL DISPOSAL OF EFFLUENT	No provision necessary	No provision necessary except for type 5.1 it is desirable	Means for chlorination is advisable, if water course is used for potable water supply.
MAINTENANCE	Cleaned approximately every 2 years	Cleaned only when absorption ceases, may be years if septic tank is kept in condition	When filtering ceases remove and replace top 2" of sand.
INITIAL COST	Usually lowest cost	More expensive than cesspools but type 5.1 is more expensive.	Most expensive. Only used where other types are not possible. Open type cheaper than closed.

DESIGN of SEWAGE DISPOSAL SYSTEMS

EXPLANATION of TABLES BELOW

"No. of persons served" in 1st column below refers to "Residential Work". To use tables for other types of buildings multiply this "No. of persons served" by the conversion factor in the last column to the right and select data on the same line and to the right of the resulting "No. of persons served".

TYPE of BUILDING	GALS of SEWAGE per PERSON	CONVERSION FACTORS
Residential	50 ✓	1. (unity)
Camps	25	.5
Summer Cottages, small farms	40	.8
Day schools, factories without kitchens or showers	15 to 25	.3 to .25
" " " with " and	30 to 50	.6 to .5
Institutions except hospitals	100	2.
Hospitals	150 to 250	3. to 5.

TABLE A — SEPTIC & SIPHON TANKS

NO. OF PERSONS SERVED	Septic tank: Gals working capacity	Septic tank: length	Septic tank: width	Septic tank: air space	Septic tank: liquid depth	Siphon tank* length	Siphon tank* width	Siphon tank* depth	Siphon: size	Siphon: drawing depth	Concrete thickness: walls	Concrete thickness: top	Concrete thickness: bottom
1-4	325	5'-0"	2'-6"	1'-0"	3'-6"								
5-9	450	6'-0"	2'-6"	1'-0"	4'-0"	*3'-0"	*2'-6"	*3'-0"	3"	1'-6"	6"	4"	6"
10-14	720	7'-0"	3'-6"	1'-0"	4'-0"	*3'-6"	*3'-6"	*3'-0"	3"	1'-6"	6"	4"	6"
15-20	1000	8'-0"	4'-0"	1'-0"	4'-0"	4'-0"	4'-0"	3'-0"	4"	1'-8"	6"	4"	6"
21-25	1250	9'-0"	4'-6"	1'-0"	4'-5"	4'-6"	4'-6"	3'-0"	4"	1'-8"	7"	5"	6"
26-30	1480	9'-6"	4'-8"	1'-3"	4'-6"	4'-8"	4'-8"	3'-6"	4"	2'-2"	8"	5"	6"
31-35	1720	10'-0"	5'-0"	1'-3"	4'-8"	5'-0"	5'-0"	3'-6"	4"	2'-2"	8"	5"	6"
36-40	1950	10'-6"	5'-3"	1'-3"	4'-9"	5'-3"	5'-3"	3'-6"	4"	2'-2"	9"	5"	6"
41-45	2175	11'-0"	5'-6"	1'-3"	4'-10"	5'-6"	5'-6"	3'-6"	5"	2'-2"	9"	5"	6"
46-50	2400	11'-6"	5'-9"	1'-3"	5'-0"	5'-9"	5'-9"	3'-6"	5"	2'-2"	9	5	6

*Not essential for these sizes

TABLE B — LEACHING CESSPOOL DISPOSAL

NO. OF PERSONS SERVED	*For rapid absorption: no. of cesspools	dia.	depth	absorptive area per person	*For medium absorption: no. of cesspools	dia.	depth	absorptive area per person	*For slow absorption: no. of cesspools	dia.	depth	absorptive area per person
1-4	1	5'-0"	5'-0"	24.5	1	6'-0"	6'-0"	35.	2	5'-0"	5'-0"	49
5-9	1	6'-0"	6'-0"	15.7	2	6'-0"	6'-0"	31.3	2	8'-0"	7'-0"	40
10-14	1	8'-0"	6'-0"	14.4	2	8'-0"	6'-0"	20.7	2	10'-0"	8'-0"	46.7
15-20	2	6'-0"	6'-0"	14.1	2	9'-0"	7'-0"	26.14	3	10'-0"	8'-6"	49.5
21-25	2	7'-0"	6'-0"	13.6	2	10'-0"	8'-0"	27.1	4	9'-0"	8'-6"	46.4
26-30	2	8'-0"	6'-0"	13.4	3	9'-0"	7'-0"	26.14	4	10'-0"	8'-6"	43.6
31-35	1 / 1	8'-0" / 9'-0"	7'-0"	13.6	1 / 2	9'-0" / 10'-0"	7'-0" / 8'-0"	26.1	5	10'-0"	8'-0"	46.7
36-40	1 / 1	9'-0" / 9'-0"	7'-0" / 8'-0"	13.7	4	9'-0"	7'-0"	26.1	4	12'-0"	10'-0"	48.9
41-45	3	8'-0"	6'-0"	13.4	4	9'-0"	8'-0"	25.7	5	12'-0"	10'-0"	54.5
46-50	2	10'-0"	8'-0"	13.0	4	10'-0"	8'-0"	26.1	5	12'-0"	10'-0"	48.9

TABLE C — SUBSOIL DISPOSAL DRAINS-4" / TABLE D — SAND FILTERS

NO. OF PERSONS SERVED	Table C lineal feet: *rapid absorp.	*med. absorp.	*slow absorp.	Table D area required in square ft: open	closed
1-4	100	150	250	100	200
5-9	200	350	700	450	900
10-14	340	500	1000	700	1400
15-20	475	650	1250	1000	2000
21-25	600	800	1500	1250	2500
26-30	725	1025	1800	1500	3000
31-35	850	1150	2100	1750	3500
36-40	975	1300	2400	2000	4000
41-45	1100	1450	2700	2250	4500
46-50	1200	1600	3000	2500	5000

Capacity of above septic tanks is based on 50 gallons flow of sewage per person for 24 hours, and is for residential work. To design tanks of other sizes use the following formulae.
Number of persons served × gallons of sewage per person = gallons capacity (of liquid)

$\frac{\text{gallons capacity}}{7.5}$ = cu. ft. capacity (of liquid).

1 Cu ft = 7.48 gallons 1 gallon = .13+ cu. ft.

Length of tanks should be approximately twice width. Minimum liquid depth 3'-6".

When purchasing a pre-fabricated septic tank, require Manufacturers guarantee that the tank will treat the gals capacity as above calculated within a 24 hour period.

Capacity of above cesspools based on 50 gallons flow of sewage per person per 24 hours, and is for residential work; to design other sizes use the following formulae. Select absorptive area per person from above.
Absorptive area per person × number of persons = Total absorptive area.
Total absorptive area = area of walls (below inlet) + area of bottom. N.Y. State allows bottom area only.
Total absorptive area = $2\pi R \times$ height $+ \pi R^2$

Absorptive areas for given sizes in square feet:—

5' dia × 5' depth = 99	8' dia × 6' depth = 201	9' dia × 8' depth = 293
6' " × 6' " = 142	8' " × 7' " = 216	10' " × 8' " = 330
7' " × 6' " = 170	9' " × 7' " = 262	12' " × 10' " = 489

Assuming 1' wide absorption trench bottom. These lengths are based on lineal ft. per person:— Rapid absorp. 24, Med absorp. 34, Slow absorp. 60. Reduce lin. ft. for wider trenches.

These areas are based on 1 gallon per sq foot per day for closed and 2 gallons per sq foot per day for open filters.

***METHOD of RELATIVE ABSORPTION DETERMINATION** (to select proper table above)

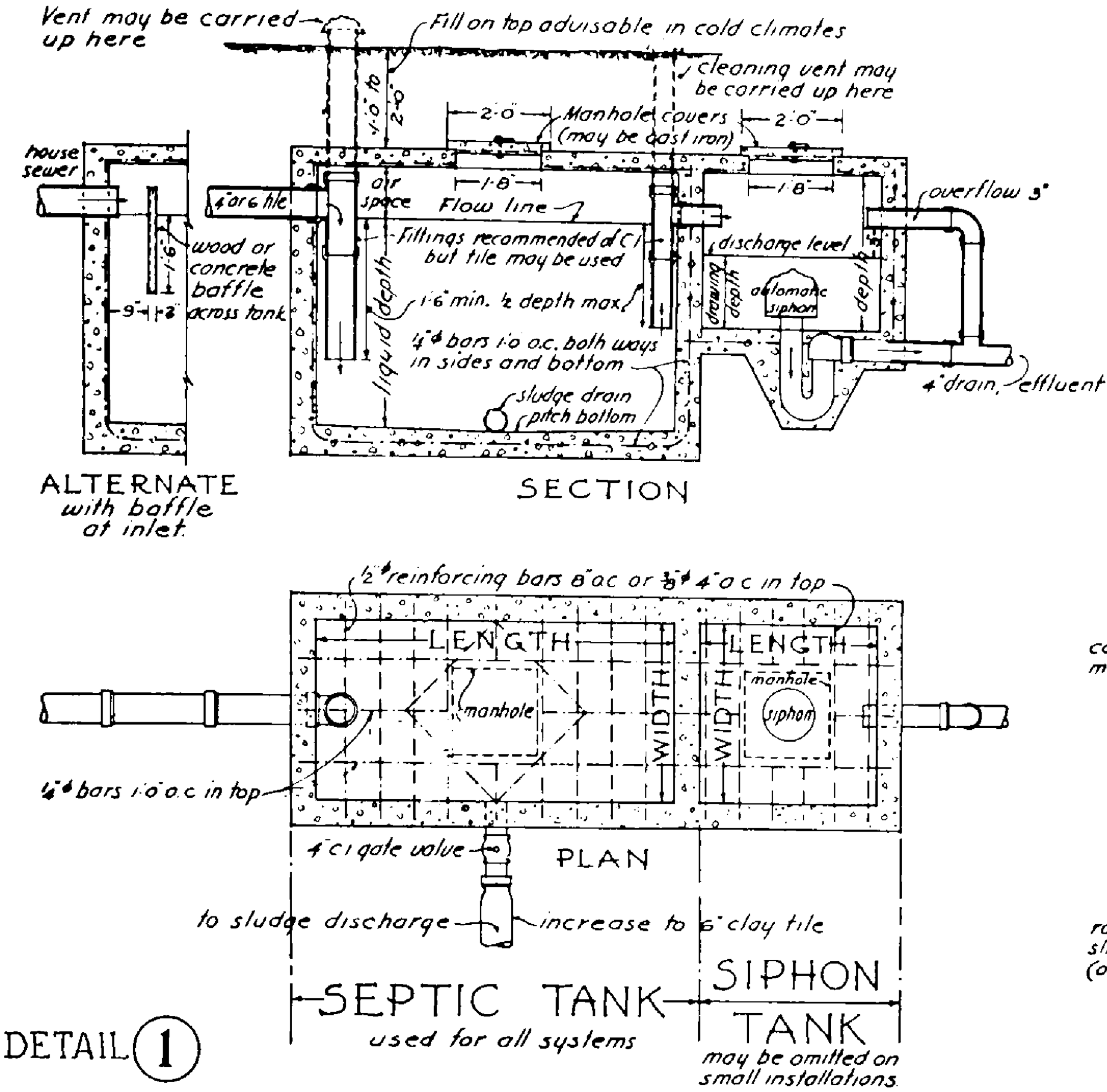
Dig test pit 12" square × 1'-6" deep on disposal site. For cesspool locate pit ½ distance between inlet and bottom. For drains locate this at grade. Quickly fill pit with 6" of water and time its disappearance. Divide time in seconds by 6. Result is time required for water to drop 1"

MINUTES REQUIRED FOR WATER TO DROP 1 INCH	RELATIVE ABSORPTION	TYPE OF SOIL	DISPOSAL METHOD RECOMMENDED
0 to 3	Rapid absorption	Coarse sand or gravel	Cesspool or drains.
3 to 5	Medium "	Fine sand, sandy loam	" " "
5 to 30	Slow "	Clay with sand or loam	" " "
30 to 60	Semi-impervious	Dense clay	Drns. collect.ᵍ drns. filters
60 & over	Impervious	Hard pan, rock	Filters.

Checked by Ralph Eberlin, C.E.

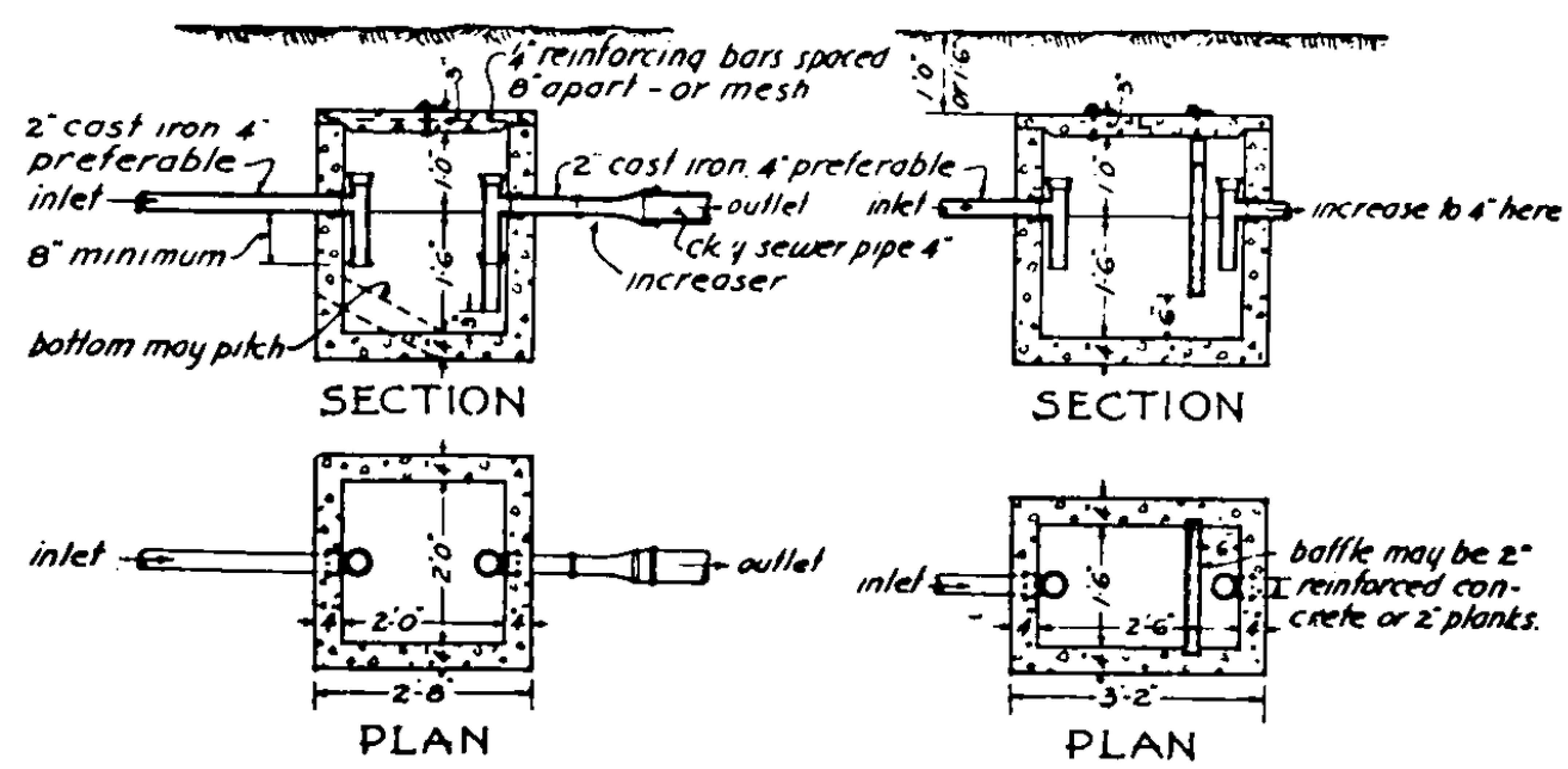
*Adapted from Architectural Graphic Standards by Ramsey & Sleeper

SEWAGE TREATMENT —SMALL SYSTEMS*—DETAILS



DETAIL (1)

Cylindrical Brick tanks of 4" or 8" walls, parged on inside & outside, corbelled dome, with adjoining siphon tank of similar shape and construction are commonly used, other features follow above septic tank.



SQUARE TYPE WITHOUT BAFFLE
Vol. = 6 cu. ft.

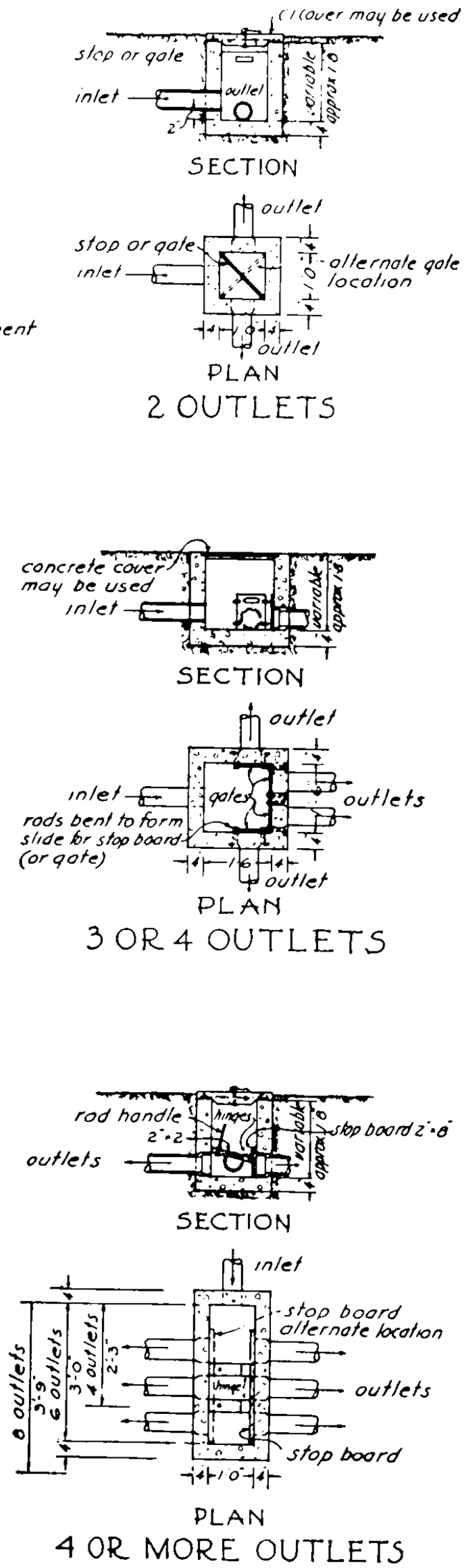
RECTANGULAR TYPE WITH BAFFLE
Vol. = 5.625 cu. ft.

Cast Iron connections shown but these may be clay tile for economy
May have 8" brick walls

DETAIL (2) Scale - ¼" = 1 Foot

GREASE TRAPS (MAY BE OMITTED IN SMALL SYSTEMS.)

Checked by Ralph Eberlin, C.E.



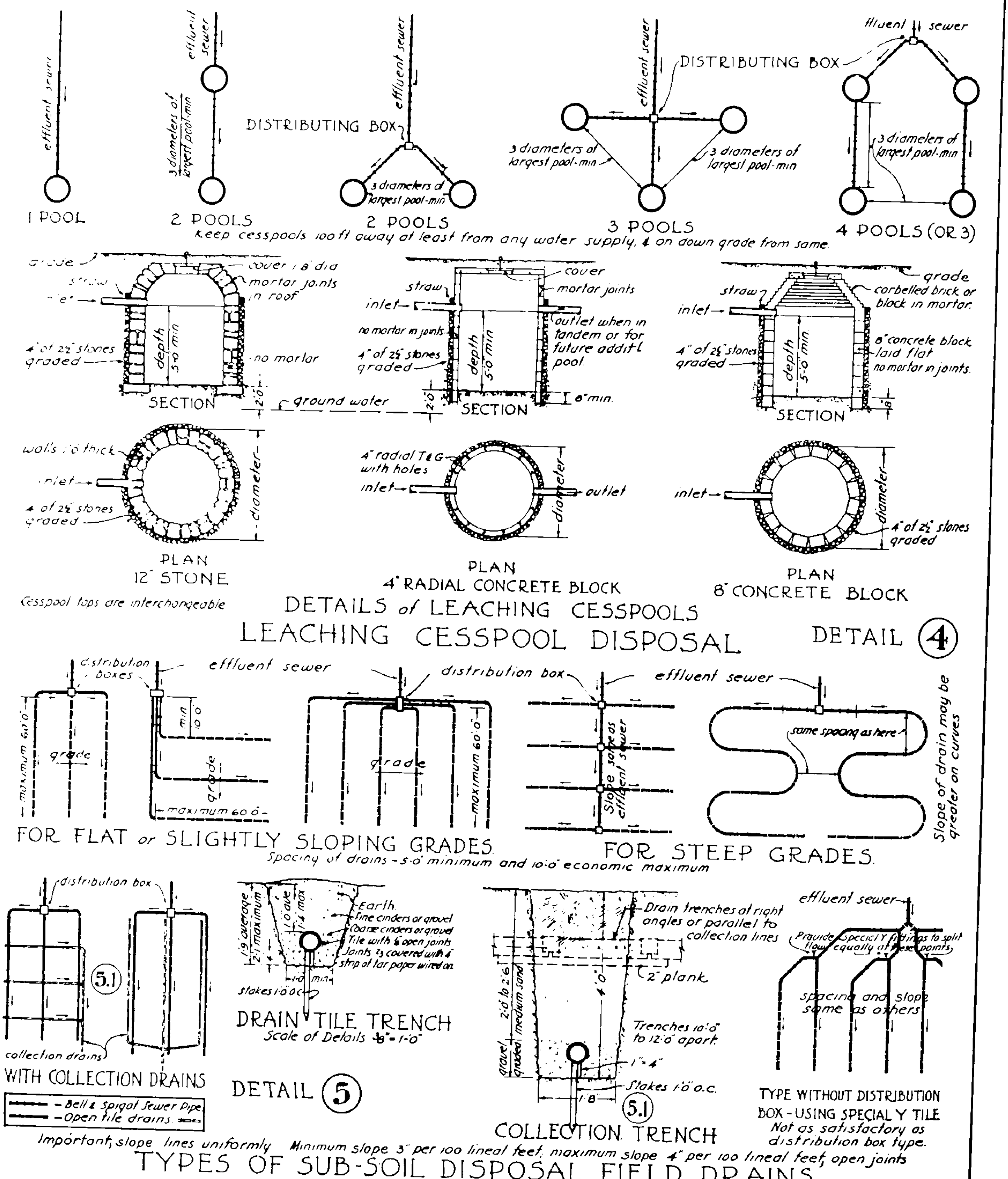
DETAIL (3)

DISTRIBUTING BOXES

All outlets must be set exactly level. Stop boards are used to provide a rest period for a part of the disposal field. Always used for filter beds and recommended for all but very small installations of all types.

*Adapted from Architectural Graphic Standards by Ramsey & Sleeper.

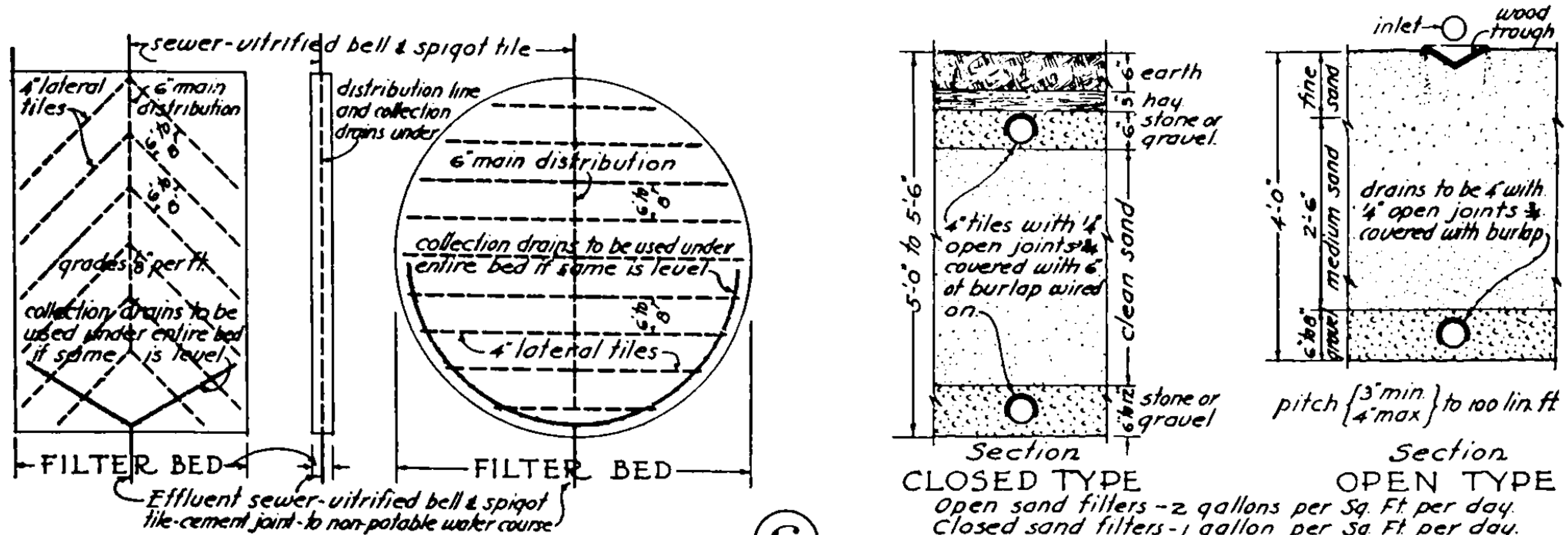
SEWAGE TREATMENT - SMALL SYSTEMS*- DETAILS



Checked by Ralph Eberlin, C.E.

*Adapted from Architectural Graphic Standards by Ramsey & Sleeper.

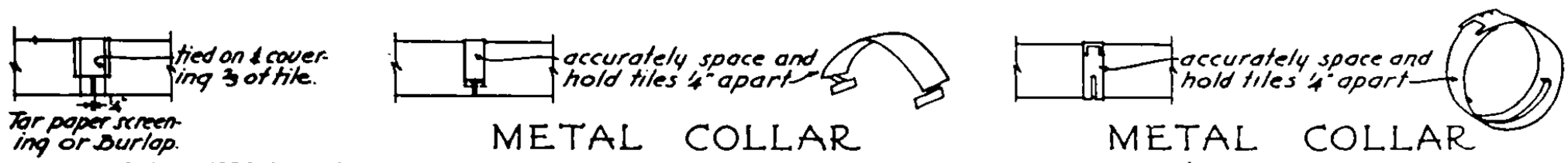
SEWAGE TREATMENT - SMALL SYSTEMS*- DETAILS



Open sand filters - 2 gallons per Sq. Ft. per day.
Closed sand filters - 1 gallon per Sq. Ft. per day.

RECTANGULAR LONG ROUND (6) DETAILS

SAND FILTERS



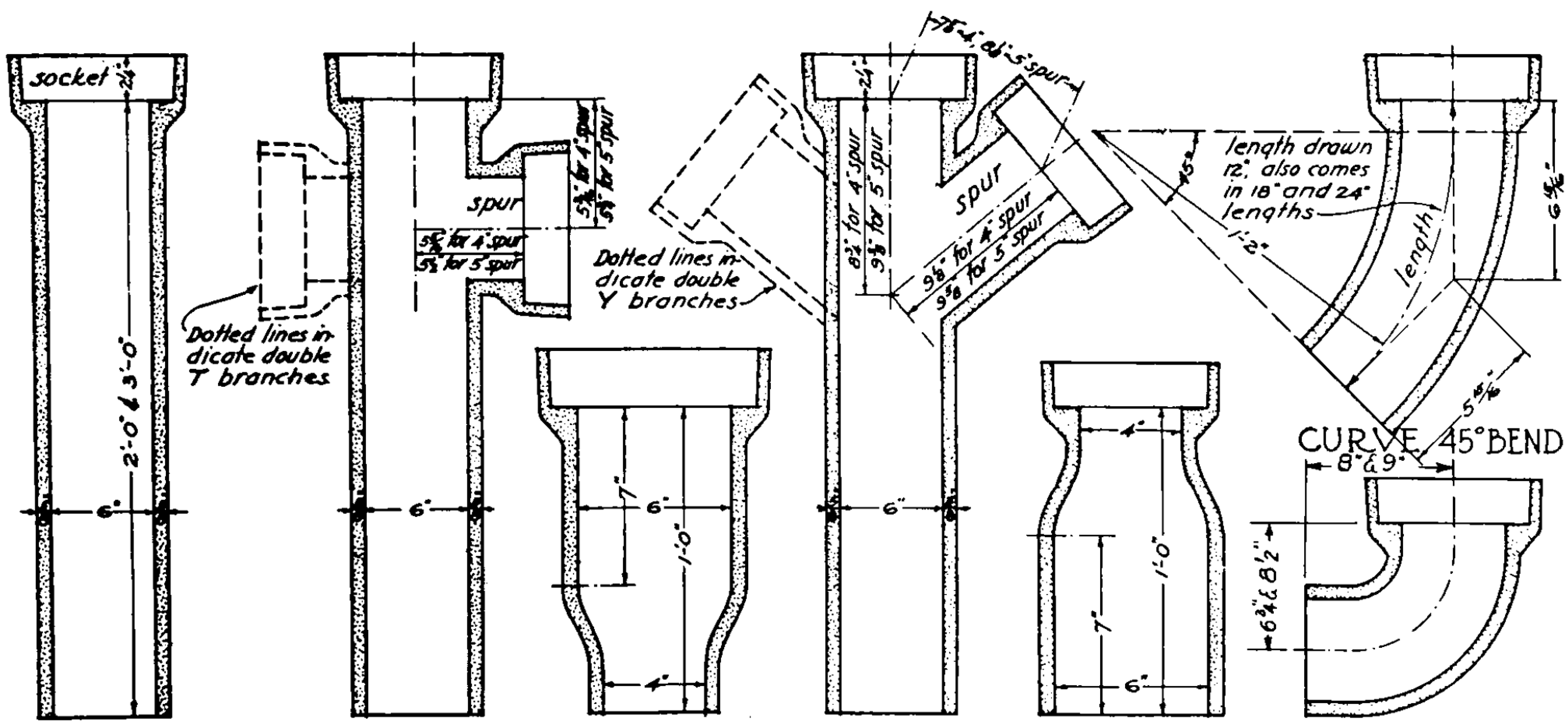
METAL COLLAR METAL COLLAR

JOINTS FOR DRAINAGE TILE, CONNECTORS & COLLARS

SPECIAL Y BRANCH | ROUND | HEXAGON | ROUND TILE ON FOUNDATION BLOCK | U-TILE ON HOLLOW FOUNDATION BLOCKS | HORSE SHOE (5" USUALLY)

2 foot lengths - inside diameter usually 4"

TYPES OF DRAINAGE TILES



PIPE | T BRANCH | REDUCER | Y BRANCH | INCREASER | ELBOW-90° BEND

These drawings are made for 4" pipe and fittings at 1½" scale — Dimensions on same refer to 6" pipe and fittings.

SALT GLAZED VITRIFIED SEWER PIPE FITTINGS

Checked by Ralph Eberlin, C.E.

**Adapted from Architectural Graphic Standards by Ramsey & Sleeper.*

SEWAGE TREATMENT - ANALYSES AND TESTS - 1

CHARACTERISTICS OF SEWAGE

The term "characteristics of sewage" signifies the quantity and character of organic and inorganic matter in domestic and industrial sewages in proportion to the amount of water they contain. A sewage is considered strong or weak according to whether or not the amount of objectionable substances it contains is above or below the average. The strength of domestic sewage depends principally upon the quantity of water used per capita in residences, commercial buildings, and institutions, and also upon the volume of ground water and storm flow entering the sewers. The variations in the strength of industrial sewages are caused by the difference in the quantity of organic wastes and chemical substances resulting from industrial activities.

TYPICAL CHEMICAL ANALYSES OF SEWAGE, PARTS PER MILLION*

Constituents	Strong	Medium	Weak
Solids, Total	1000	500	200
Volatile	650	350	120
Fixed	350	150	80
Suspended, Total	500	300	100
Volatile	400	250	70
Fixed	100	50	30
Dissolved, Total	500	200	100
Volatile	250	100	50
Fixed	250	100	50
Biochemical oxygen demand 5-day, 20°C.	300	200	100
Oxygen consumed	150	75	30
Dissolved oxygen	0	0	0

Constituents	Strong	Medium	Weak
Nitrogen, Total	86	50	25
Organic	36	20	10
Free ammonia	50	30	15
Nitrites (NO_2)	0.10	0.05	0.00
Nitrates (NO_3)	0.40	0.20	0.10
Chlorides	175	100	15
Alkalinity	200	100	50
Fats	40	20	0

*Adapted from Sewerage and Sewage Treatment by Harold E. Babbitt.

MOST IMPORTANT ANALYSES TO MAKE AT SEWAGE WORKS*

Source of Sample	5-day B.O.D.	Solids: Suspended Total	Solids: Suspended Volatile	Solids: Settleable	Nitrogen: Total organic	Nitrogen: Nitrate	Dissolved Oxygen	Relative Stability	Residual Chlorine	Bacteria: Total	Bacteria: *B. coli* (presumptive test)
Raw sewage	I	I	II	I	II						
Settled sewage	I	I		I	II						
Oxidized effluent	I	I		I	II	I	II	II			
Activated-sludge aeration tank		I[a]		I[a]							
Chlorinated effluent							I				
Stream or other diluting water	I								I	II	II
Sludge-digester overflow	I	I					I				III

[a]The sludge index, which can be calculated from the suspended and settleable solids, is valuable in controlling the operation of activated-sludge aeration tanks.

Key:
- I. Tests having the greatest value.
- II. Tests having less value.
- III. Tests that need be made only when conditions warrant.

*From Keefer's Sewage Treatment Works, page 590.

SEWAGE TREATMENT - ANALYSES AND TESTS - 2

Notes: A. For outlined method of tests, see most recent edition of "Standard Methods for the Examination of Water & Sewage," published by the American Public Health Association.

B. General reasons for tests:

1. Sewage or waste analysis may determine type of plant to be used.
2. Determine plant efficiency.
3. Provide basis for plant control.
4. Compliance with state laws.
5. Guide for future design and extensions of existing plants.

(Tests most frequently made are preceded by an asterisk. The numbers in parentheses refer to similar numbers in preceding columns.)

Interpretation of Sewage Analyses and Sewage Plant Operating Records

Test	Units	Sampling Points	Reason for Test	Analysis and Interpretation of Results	Brief Procedure of Test *
Screenings (1) Quantity. (2) Moisture content.	(1) Lb. or cu. ft. per million gal. (2) % of solids.	As removed from screens.	(1) a. To determine time periods for intermittent operation of mechanical equipment. b. To determine time periods for collection by trucks. c. To reveal abnormal contributions to system. d. To complete record of solids removal by plants. (2) To determine whether or not screenings have been drained sufficiently to be burned efficiently in incinerator.	(1) Quantity from coarse screens ($\frac{1}{2}$"-3" openings) usually 0.5 to 6 cu.ft. per million gals. Quantity from fine screens ($\frac{3}{4}$"- 3/32" openings) usually 5 to 30 cu.ft. per million gals. Weight per cu.ft. 40 to 60 lbs. Variations from above values and the average from the plant in question may indicate large contributions from industrial, commercial, or similar sources. (2) Usual % of moisture between 75% and 90% in screenings by ordinary draining for one day. Dewatering centrifuges and presses usually reduces % moisture to 60 to 75%. To feed incinerator economically, screenings should contain between 60 and 80% moisture. B.t.u. used per lb. of screenings incinerated ranges between 1400 and 3500.	(1) The quantity is measured by weighing a day's collection of the material which has been allowed to drain; or the volume is measured. (2) The % moisture is determined by weighing and drying a representative sample of about 1 lb. in an oven at 103°C. for 12 to 24 hr. Sample is weighed while still warm and loss of weight divided by weight of dry solids multiplied by 100 is the % moisture.
Grit (1) Volume. (2) Size and type of solids being removed. (For sieve test and	Lb. or cu. ft. per million gal.	As removed from grit chambers.	(1) To determine time periods for manual cleaning and setting of time periods for intermittent operation of mechanical grit removers.	(1) For combined sewers, average quantity of grit commonly deposited is from 2 to 3 cu. ft. per million gal. To allow for maximum storm demands between cleaning operations, 10 to	(1) Quantity is measured by weighing the amount collected in one day after it has been allowed to drain; or the volume is measured.

* Tests followed by dagger (†) are from National Line Association pamphlet on Principles of Sewage Treatment.

SEWAGE TREATMENT - ANALYSES AND TESTS - 3

Test	Units	Sampling Points	Reason for Test	Analysis and Interpretation of Results	Brief Procedure of Test
volatile solids test. see test under item "Sludge.")			(1) To complete the records of solids removed by the plant.	30 cu. ft. per million gal. grit storage space is generally provided in grit chamber channels. Grit chambers should be cleaned about every 2 weeks under normal conditions and every few days at times of successive storms. Large amounts of grit gathering in screening chamber in sanitary sewage treatment plant may indicate broken lines, presence of illegal storm drain connections, open manholes, etc. Modern tendency is to provide a grit chamber for treatment plants treating sanitary sewage as well as for those treating combined sanitary sewage and storm drainage.	
Scum or skimmings (not a customary test).	Cu. ft. per million gal.	(1) Grease or skimming tanks. (2) Settling tanks. (3) Filters. (4) Aerators, etc.	To determine efficiency of skimming tanks. To determine whether additional amount of air is necessary to increase flotation of grease.	Amount skimmed from tanks varies from 0.1 to 5.0 cu. ft. per million gal. Volume above normal may indicate industrial, garage, etc., waste discharge. Grease causes clogging of pipes and should be removed as early as possible in the treatment process. Grease and scum should not be put in digesters because it interferes with digestion and drying of the sludge.	Can be measured by allowing the collected material to stand in a tank until separation of the water and scum takes place. The water is drawn from the bottom of the tank and the volume occupied by the scum measured. Care should be taken to ascertain if gases in the scum have escaped, causing the scum to settle as sludge. Sludge settling with the water should be measured as part of the scum.
*Total suspended solids (includes settleable and non-settleable solids).	Parts per million (p.p.m.).	(1) Raw sewage primary. (2) Settling tank effluent. (3) Filter effluent.	To determine reduction of suspended solids by plant as a whole to satisfy requirements set by State health authorities for water course into which effluent is finally placed.	See Tables No. A, B, and C, page 5-40, for average values of raw sewage, and values and efficiency of removal to be expected from the various units and the plant as a whole. Higher amounts of suspended solids	A Gooch crucible is prepared, ignited, and weighed. A sample of sewage or effluent of 50 to 100 milliliters (ml.) is filtered through and the crucible is dried for at least $2\frac{1}{2}$ hr. in an oven at 103°C.

SEWAGE TREATMENT - ANALYSES AND TESTS - 4

Test	Units	Sampling Points	Reason for Test	Analysis and Interpretation of Results	Brief Procedure of Test
		(4) Final effluent. (5) Aeration Tanks. (6) Supernatant from digestors.	To determine reduction of suspended solids by each unit in the plant. (5) To determine characteristics of activated sludge, or the sludge index, to ascertain the proportion of the material which settles with difficulty.	in raw sewage may indicate industrial wastes or low per capita flow. Smaller amounts of suspended solids and large flows may indicate infiltration. Lower efficiencies than normally expected may indicate that units should be cleaned and mechanical equipment adjusted more often (tanks and filters). The low efficiencies may also indicate that the re-circulation ratio in high rate trickling filters should be changed, or that the amount of return activated sludge and air supply in aeration tanks should be increased. (5) Aeration tank samples (activated sludge process). Limits of suspended solids in mixed liquor should be 1200 to 3000 p.p.m. for diffused aeration plants and 500 to 1200 p.p.m. in mechanical aeration plants. (5) "Sludge index" of 100 is normally expected in diffused air plants. "Sludge index" may be as high as 300 in mechanical aeration plants. "Bulking" occurs with higher "sludge indices." When bulking occurs, sludge rises and flows over effluent weirs.	It is then cooled in in a desiccator, weighed, and the parts per million (p.p.m.) suspended solids calculated by multiplying the gain in weight in milligrams by one thousand divided by the ml. of sample taken. (5) Sludge index is the volume in milliliters occupied by one gram of dry suspended matter after the aerated liquor has settled for 30 min. A one liter sample from the outlet of the aeration tank is settled 30 min. in a 100 ml. graduated cylinder and the volume occupied by the sludge is reported in milliliters. The dry suspended solids are then determined in parts per million. Computation: (ml. settleable sludge ÷ p.p.m. suspended solids) x 1000.†
Total solids (includes screenings, grit, scum, suspended solids and dissolved solids).	P.p.m.	(1) Raw sewage. (2) Final effluent.	To determine characteristics and condition of the sewage. To reveal industrial wastes.	The following are the average p.p.m. of total solids that different strengths of sewage would contain. Weak, 400 p.p.m. medium, 700 p.p.m. strong, 1200 p.p.m.	Total solids are determined by drying at 103°C. a sample of 50 ml. in a silica dish, which previously has been ignited and weighed. The dish containing the dry solids is cooled in a desiccator and

SEWAGE TREATMENT - ANALYSES AND TESTS - 5

Test	Units	Sampling Points	Reason for Test	Analysis and Interpretation of Results	Brief Procedure of Test
				Suspended solids are usually about ½ of the total solids. For industrial wastes, some dissolved solids may have to be removed before the effluent is put into waterway.	weighed. The calculation is the same as that for suspended solids.†
Dissolved solids.	P.p.m.	(1) Raw. (2) Primary settling tank effluent. (3) Filter effluent. (4) Final effluent.	To reveal breaking down of sewage during treatment and effectiveness of treatment on the portion of organic matter which is in solution.	Indicates age of sewage. The more stale the sewage is the greater the per cent of dissolved solids. For domestic sewage, dissolved solids have normally little meaning. Dissolved solids in domestic sewage is usually approximately 2/3 of total solids. For industrial wastes, dissolved solids may have large B.O.D. requirements which must be satisfied.	Dissolved solids are determined by subtracting the total suspended solids from the total solids.
Volume of settleable solids.	C.c. or ml. per liter.	(1) Raw sewage. (2) Final effluent.	Where primary treatment is used and laboratory facilities are limited, test affords approximate measure of performance.	Imhoff tanks and primary settling tanks should remove about 45 to 60% of suspended solids.	An Imhoff cone is filled to the liter mark with a thoroughly mixed sample. Settled for 1.75 hr; the material clinging to sides is gently knocked down and settled 0.25 hr. longer. The ml. of settleable solids is then read on the Imhoff cone graduations.
pH (Hydrogen ion concentration).		(1) Raw sewage. (2) Primary tank effluent. (3) Final effluent. (4) Sludge in settling tank.	(1) To reveal staleness and presence of industrial wastes in raw sewage. (1) To determine proper kind of chemicals and dosage in chemical treatment plants for good coagulation and precipitation. 2),3),4) To determine pH in order to control conditions in the tanks, by adding necessary chemical, so as to promote bacterial activity and prevent sludge bulking.	(1)pH values in raw sewage lower than the pH of the water supply indicate septic or stale sewage or presence of industrial wastes. pH values higher than that of the water supply also indicate industrial wastes. (1) In chemical treatment, the various coagulants give best results for specific ranges of pH. Coagulant pH range:	The hydrogen ion concentration of sewage and sludge is determined by colorimetric methods (color comparison). Color indicators for pH ranges between 5.2 and 9.6 are of greatest use. Sludge samples are diluted with nine times their volume of distilled water and allowed to settle. The supernatant is decanted and used for the determinations. Electrometric methods are used for more precise determinations.†

SEWAGE TREATMENT - ANALYSES AND TESTS-6

Test	Units	Sampling Points	Reason for Test	Analysis and Interpretation of Results	Brief Procedure of Test
				Aluminum sulphate (alum), 5.5 to 8.0 Ferrous sulphate, 8.5 " 11.0 Ferric sulphate, 5.0 " 11.0 Ferric chloride, 5.0 " 11.0	
		(5) Sludge in digestion tanks.	(5) To determine the condition of the sludge in the separate digestion tanks, or in the digestion chamber of an Imhoff tank. (5) To determine dosage for coagulation prior to vacuum filtration.	(5) For proper digestion of sludge, the pH value should be kept above 7.3. Values lower than 7.0 indicate acid condition and should be corrected by addition of lime to digesters.	
Total alkalinity.	P.p.m. in terms of $CaCO_3$	(1) Raw sewage primary. (2) Tank effluent. (3) Final effluent.	To determine efficiency of chemical treatment plants.	High values in raw sewage indicate industrial wastes. Domestic sewage is normally alkaline (approximately 20 to 40 p.p.m.).	To a 100 ml. sample of sewage 4 drops of methyl orange indicator are added and the sample is titrated to the end point with N/50 sulfuric acid. The ml. of acid used are multiplied by 10 to give p.p.m. total alkalinity as calcium carbonate.
Total acidity.	P.p.m. in terms of $CaCO_3$.	(1) Raw sewage primary. (2) Tank effluent. (3) Final effluent.	To determine efficiency of chemical treatment plants.	High values in raw sewage indicate industrial wastes. Domestic sewage is normally alkaline (approximately 20 to 40 p.p.m.).	Ten drops of phenolphthalein are added to a 100 ml. sample of sewage and the sample is titrated with N/50 sodium hydroxide until a permanent end point is reached. The calculation is the same as that for alkalinity.
Sludge. (1) Moisture and total solids. (2) Ash and volatile. (3) Temperature of sludge in digesters.	(1) Solids and moistures in % of sample of sludge. (2) Ash and volatile matter in % of dry solids.	(1 and 2) Fresh sludge. (1,2,and 3) In Imhoff tank and separate digestion tanks. (1) Sludge bed before and after drying.	For control of sludge works, drying, vacuum filtration, digestion, or incineration.	(1) Moisture of fresh and digested sludge is usually between 85 and 99% dependent upon the process of treatment. In general the longer the sludge is digested and the greater the amount of supernatant removed, the less will be its moisture content. Vacuum filters and centrifuges will produce a sludge cake	(1) Moisture and total solids: Weigh 50 grams of sludge as rapidly as possible in a tared evaporating dish. Evaporate to dryness overnight in an oven at 103°C., cool in a desiccator and reweigh or evaporate on a water bath, dry at 103°C., cool, and weigh to constant weight.

SEWAGE TREATMENT - ANALYSES AND TESTS - 7

Test	Units	Sampling Points	Reason for Test	Analysis and Interpretation of Results	Brief Procedure of Test
		(1) Before and after vacuum filtration.		with a moisture content between 55 and 85%. Sludge must be conditioned with chemicals prior to vacuum filtration. Doses of lime, 5 to 15% of the dry solids, and doses of ferric chloride, 1 to 5% of the dry solids are generally effective. When sludge is dewatered to 80% moisture or less it may be mixed with garbage and rubbish and burned in an incinerator. High moisture content indicates ineffective concentration. (2) High ash reflects grit or industrial wastes. Low reduction of volatiles during digestion indicates low efficiency of digestion. (3) Best temperature for mesophilic (medium temperature) digestion 85° to $95^{\circ}F$. normally should be maintained in digesters. Best temperature for thermophilic (heat loving) bacteria is $125^{\circ}F$.	(2) Volatile solids and ash: Ignite the residue from the determination of moisture in an electric muffle at $600^{\circ}C$. (dull red heat) for 60 min. Cool in a desiccator and reweigh.
Relative stability (putrescibility)	Stability or days required for decolorization.	(1) Filter effluent. (2) Final effluent. (3) Stream above. (4) Stream below.	To determine the % of oxygen available as dissolved nitrite nitrate, oxygen to the total oxygen required to satisfy the B.O.D. To determine adequacy of treatment for discharge into receiving stream. This determination is being replaced by more exact tests, such as		Fill a 150 ml. glass-stoppered bottle with sample, avoiding aeration. Add exactly 0.4 ml. of methylene blue indicator solution below the surface of the liquid. Incubate at $20^{\circ}C$. with a water seal, observing the sample daily until decolorization takes place. Results are reported as follows:

SEWAGE TREATMENT - ANALYSES AND TESTS - 8

Test	Units	Sampling Points	Reason for Test	Analysis and Interpretation of Results	Brief Procedure of Test
			dissolved oxygen, nitrite, nitrate, and B.O.D. tests. For small plants with limited facilities it is useful for indicating satisfactory operation of the biological oxidation processes.		Days % stability 1 21 3 50 5 68 7 80 10 90 12 94 14 96 16 97 18 98 20 99
Oxygen consumed (test now being largely superseded by B.O.D. test).	P.p.m.	(1) Raw sewage. (2) Tank effluent. (3) Final effluent.	To measure plant efficiency in removing organic matter which takes up oxygen from receiving stream. Used in conjunction with B.O.D. test.	As a result of these tests, sewage may be classified as: Weak .... 75 Medium .... 165 Strong .... 265 This classification influences the size of filters.	A sample of sewage or effluent of 5 to 100 ml. is poured into a 250 ml. flask. The total volume is made up to 100 ml. with distilled water. 10 ml. of 1:3 sulfuric acid and 10 ml. of a standardized potasium permanganate solution (1 ml. = 0.1 mg. of oxygen) are added. The flask is then submerged in boiling water for 30 min. 10 ml. of an ammonium oxalate solution equivalent to the permanganate are added. The flask is removed from the bath and the sample is titrated with permanganate solution to a permanent pink color. A blank determination is run on distilled water. The oxygen consumed value in p.p.m. is calculated by subtracting the number of ml. of permanganate used for the blank from the number used in the determination, multiplying by 1000, and dividing by 10 times the volume of sample in ml.†
Dissolved oxygen (D.O.).	P.p.m.	(1) Raw sewage. (2) Filter and aerator effluent. (3) Final effluent.	To check performance, particularly of aeration tanks and filters.	Presence of dissolved oxygen (D.O.) 1 p.p.m. or more in raw sewage usually indicates fresh sewage and may indicate infiltration. Stale and septic sewage contains no	A 300 ml. glass-stoppered bottle is filled completely with the sample; a minimum of disturbance and precautions are taken to prevent the entrainment of

SEWAGE TREATMENT - ANALYSES AND TESTS - 9

Test	Units	Sampling Points	Reason for Test	Analysis and Interpretation of Results	Brief Procedure of Test
		(4) Receiving stream above and below point of discharge of sewage effluent.		dissolved oxygen. Solubility of atmospheric oxygen in water in summer is about 5 to 7 p.p.m., in winter about 10 to 12 p.p.m.	of air bubbles. 0.7 ml. of concentrated sulfuric acid and 1 ml. of potassium permanganate solution are added below the water surface. After the stopper is replaced, the bottle is shaken and allowed to stand for half an hour. The stopper is removed and 1 ml. of ammonium oxalate solution is added; the stopper is replaced and the bottle reshaken. When the pink color disappears the stopper again is removed and 2 ml. of manganese sulfate and 3 ml. of alkaline potassium iodide solution are added below the surface. The stopper is immediately replaced and the bottle thoroughly shaken. The precipitate that forms is allowed to settle, the stopper is removed, and 1 ml. of concentrated sulfuric acid is added. Again the stopper is replaced and the bottle shaken until the precipitate is completely dissolved. Iodine is liberated in proportion to the amount of dissolved oxygen that was present. A 200 ml. sample is withdrawn from the bottle and titrated with 0.125 N sodium thiosulfate solution to the starch end point. The number of ml. of sodium thiosulfate solution used is equivalent to the p.p.m. dissolved oxygen present in the sample.†
*Biochemical oxygen demand (B.O.D.).	P.p.m.	(1) Raw sewage. (2) Primary tank effluent.	This is one of the basic methods of evaluation of plant efficiency and adequacy of receiving	See Tables A,B, and C, page 5-40, for average values of raw sewage, and values and efficiency	The biochemical oxygen demand of a sample of sewage is determined by making three dilutions of the sample

SEWAGE TREATMENT - ANALYSES AND TESTS - 10

Test	Units	Sampling Points	Reason for Test	Analysis and Interpretation of Results	Brief Procedure of Test
		(3) Filter effluent. (4) Final effluent. (5) Stream above. (6) Stream below. (7) Digestor supernatant.	stream for the required dilution of the effluent.	of removal to be expected from the various units and the plant as a whole. Higher values of B.O.D. in raw sewage may indicate industrial waste or stale or concentrated sewage. For additional comments, see test "Total suspended solids."	with buffered distilled water saturated with dissolved oxygen and placing each dilution in a 300 ml. glass-stoppered bottle which is filled to capacity. A bottle filled with the dilution water alone (blank) is included. The amount of dilution depends upon the strength of the sewage or effluent and is based on the estimated strenght range. The bottles are incubated 5 days at 20°C. On removal from the incubator, dissolved oxygen is determined on all samples. The p.p.m. B.O.D. is calculated for each dilution by subtracting the p.p.m. dissolved oxygen in the dilution from that of the dilution water blank, multiplying by 100, and dividing by the percentage dilution. Results from each dilution are averaged to give the final results.†
*Chlorine residual.	P.p.m.	Final effluent.	To determine whether sewage is being chlorinated sufficiently.	15 to 30 min. (depending on State health laws) after chlorination the chlorine residual should be 0.5 p.p.m.	Residual chlorine is generally determined by the *o*-tolidine test. Sometimes the starch-iodine test is used. *o*-Tolidine forms a yellow color with chlorine in acid solution. In making the determination, 1 ml. of *o*-tolidine is added to a 100 ml. sample of sewage or effluent. After 15 min. the color formed is compared with a series of standards in which the depth of color is equivalent to known amounts of chlorine.†
*Presumptive (*B coli*) (bacteriological)	Most probable number per millileter	Final effluent.	To determine whether sewage is being sufficiently aerated and chlorinated.	Depends on size of receiving stream. For additional information, see p. 6-30	See "Standard Methods for Examination of Water and Sewage."

SEWAGE TREATMENT - ANALYSES AND TESTS - 11

Test	Units	Sampling Points	Reason for Test	Analysis and Interpretation of Results	Brief Procedure of Test
				for extent of treatment required to change water with various amounts of B.coli into drinking water.	
Ammonia nitrogen.	P.p.m.	(1) Raw sewage. (2) Filter or aeration tank effluent. (3) Final effluent.	To determine efficiency of filters and aeration tanks in nitrification and stabilization (changing N and NH_3 to NO_2 and NO_3).	The following are the average p.p.m. of ammonia nitrogen in various strengths of raw sewage. Weak 4 p.p.m. Medium 12 p.p.m. Strong 22 p.p.m. High values in raw sewage indicate strong sewage or industrial wastes. Use results obtained for filter effluent and final effluent in conjunction with results of Nitrate-nitrite test.	100 ml. of sample are placed in graduated cylinder and 1 ml. of 10% copper sulfate solution added. Mix solution and add 1 ml. of 50% sodium hydroxide solution. Mix solution again and allow precipitate to settle. A measured portion of the clear superhatant is pipetted into a Nessler tube. Add 2 ml. of Nessler's solution and fill tube to the mark with ammonia-free water. After 10 min. the color formed is compared with permanent or previously prepared standards of known ammonia-nitrogen content. Calculate from matched standard the p.p.m. ammonia nitrogen in sample.†
Nitrates (NO_3) and nitrites (NO_2).	P.p.m.	(1) Raw sewage. (2) Filter or aeration tank effluent. (3) Final effluent.	To determine efficiency of filters and aeration tanks in nitrification and stabilization (changing N and NH_3 to NO_2 and NO_3).	Average NO_2 and NO_3 production from N and NH_3 by various processes is as follows: Trickling filters 2 to 13 p.p.m. Sand filters 4 to 12 p.p.m. Activated sludge 0.1 to 6 p.p.m. Sedimentation or Imhoff Tanks 0 p.p.m. Chemical treatment 0 p.p.m.	A 25 ml. sample of effluent is placed in a small casserole, 2 ml. of sodium hydroxide solution are added and the mixture is slowly boiled down to half volume. The sample is then washed with ammonia-free water into a large Pyrex test tube, having a 100 ml. calibration mark. The tube is filled to the mark with water and a strip of aluminum foil added. A stopper equipped with a Bunsen valve is fitted tightly into the tube. When the reaction has ceased and the liquor is clear, pipette off 50 ml. Aliquots of this sample are Nesslerized and compared with ammonia-nitrogen standards. From the matched standards.the p.p.m. of nitrogen as nitrite-nitrate is calculated.†

Fresh sewage: Contains dissolved oxygen. B.O.D. requirement (p.p.m.) is generally less than total suspended solids (p.p.m.).

Stale sewage: Contains no dissolved oxygen. B.O.D. requirement is generally higher than total suspended solids.

Septic sewage: Undergoing putrefaction in absence of oxygen. B.O.D. requirement is generally equal to or slightly less than total suspended solids.

† Tests are from National Lime Association's pamphlet on Principles of Sewage Treatment.

SEWAGE TREATMENT - LABORATORY FURNITURE*

CLASSIFICATION OF SEWAGE TREATMENT PLANTS
FOR
SCHEDULING LABORATORY FURNITURE AND EQUIPMENT

Plant Types	Classification Per 1000 Population Capacity			
	38 & Over	12 to 38	6 to 12	1.5 to 6
Complete treatment with separate sludge digesters	A	A	B	C
Primary tanks and separate digesters primary treatment only	A	B	C	C
Imhoff tanks with trickling filter or slow sand filter	B	B	C	D
Imhoff tanks only, or sand filters only	-	C	D	D

RECOMMENDED LABORATORY FURNITURE FOR SEWAGE TREATMENT PLANTS

For Type "A" plants	Items 1, 2, 3, and 4
For Type "B" and "C" plants	Items 2, 3, and 5
For Type "D" plants	No furniture

Item 1. One (1) industrial chemistry laboratory table, 72" long, 48" wide, 36" high, equipped with 32 drawers 10 1/2" wide, 16" deep, and 6 3/4" high, 4 cupboards 10 1/2" wide, 18" deep, and 27 3/4" high; one (1) bottle rack 68" long, 10" wide, and 18" high, one drain trough of lead-lined or stone construction, 66" long, 6" wide, and 3" to 6" high, and one stone sink 20" long, 12" wide, and 12" deep. The cabinet shall be built of oak, the top shall be Shelstone or Alberene stone 1 1/4" thick. The bottle rack shall be black carbonized. Equipment, 3 straight-way water cocks, one bib water cock and one set of sink fittings. Table to be equivalent to that of the following companies:

E. H. Sheldon & Co., Muskegon, Mich.	No. 11268
W. W. Kimball Co., Chicago, Ill.	No. 502
Hamilton Mfg. Co., Two Rivers, Wis.	No. L--512

Item 2. One (1) balance shelf, 3' long x 2' wide; oak construction except for 1 5/8" thick birch, black carbonized top; equipped with drawer 21" wide, 15" deep, 3 3/4" high. Shelf to be equivalent to:

E. H. Sheldon & Co.	No. 12520
W. W. Kimball Co.	No. 682
Hamilton Mfg. Co.	No. L--1174

Item 3. One (1) supply case, 48" wide, 15" deep, 80" high, upper section glazed 44" wide, 60" high, with 3 adjustable shelves; cupboard section 44" wide, 12" deep, 13" high, of oak.

E. H. Sheldon & Co.	No. 41040
W. W. Kimball Co.	No. 9562
Hamilton Mfg. Co.	

Item 4. One (1) lower section cupboard unit 37 5/8" long x 24" wide x 36" high, containing one double cupboard 34" wide x 28 1/4" high x 20.5/8" deep, with one stone sink 14 1/4" long x 10" wide x 8" deep with one set of drain fittings, one cold water pantry cock, and one double electric receptacle for 110-v A.C., table top to be scored to drain to sink.

* From Engineering Manual, War Dept., Corps of Engrs., Jan. 1943.

SEWAGE TREATMENT - LABORATORY EQUIPMENT †-1

E. H. Sheldon & Co.
W. W. Kimball Co.
Hamilton Mfg. Co. No. L--804

All furniture shall be of oak construction, natural finish throughout, except table tops, which are to be 1 5/8" birch black carbonized.

Item 5. One (1) chemistry laboratory table, 60" to 96" long, 36" high, 30" wide, with an integral sink on one end, equipped with a reagent shelf and constructed for installation against wall with cupboards and shelves below on one side only. Top to be Shelstone or Alberene stone.

RECOMMENDED LABORATORY EQUIPMENT FOR SEWAGE TREATMENT PLANTS

QUANTITY Type of Plant A & B	C	D	DESCRIPTION	CATALOGUE NUMBERS E. H. Sargent & Co.	Central Scientific Co.	Fisher Scientific Co.
1	1		Analytical balance, Chainomatic, notched beam, student model			
1	1		Balance weights, set 1 gm. to 100 gm., gold plated, no fractional, w/case	S--2675	1020	
1	1		Balance, Harvard, metric, 1 kg. beam grad. to 1/10 gm.	S--4045	8180-B	2-215
1	1		Balance weights, metric. Class C, 1 gm. to 1000 gm.	S--3215	3470	2-035
1	1		Drying oven, Thelco No. 14, 110-v	S--4285	9140	2-300
1	1		Furnace muffle, elec. Hoskins, Type F. D., size No. 202-110-v	S--64055	95000	13--265
1	1		Rheostat for muffle furnace	S--36855	13675-A	10--510
1			pH meter, one-two type control portable electrometer for pH determination w/extra glass electrode and buffer sol	S--36875	13678-A	
	1	1	Hydrogen ion apparatus color comparator--pH, LaMotte or Hellige w/bromothymol blue stds.	Cameron, Beckman, Coleman, or equal		
	1		pH standards, LaMotte or Hellige cresol red, range K	S--41725	21500-H	
	1		Indicator solution, cresol red, LaMotte or Hellige 100 ml.	S--41735	21550-K	
1	1		Mechanical refrigerator, sealed type mechanism, 6 cu.ft.	S--41745	21560-K	5--985-A
3	3	2	Imhoff cone			
1	1		Incubator, 20°, mechanical cooling, Frigidaire type, or Eimer & Amend water bath type	S--84125	29015	15--440
1	1		Sampler for sewage and sludge, brass, w/chain, pump, and air hose	Pacific Flush Tank Co., Bulletin #133		
1	1		Corks XXX assorted sizes, bag of 100	S--23055	12402	7--785
2	2		Funnels: Analytical 75 mm.	S--35315	15055	10--237
2	2		" Short stem 150 mm.	S--35305	15070	10--320
* 1			" Buechner 2 A *	S--35555	18590	10--355
3	1		Glass tubing, 5 to 10 mm., assorted per 16	S--40075	14075	11--350
1	1		Glass rod, 6 mm. per 16	S--40095	14050	11--375
2			Glass T-tubes, 8 mm.c.d.	S--82725	15650	15--325
2	1		Pipettes, transfer 100 ml.	S--69505	16355	13--650
2	1		" " 50 ml.	S--69505	16355	13--650
2	1		" " 25 ml.	S--69505	16355	13--650
2	1		" " 10 ml.	S--69505	16355	13--650
2	1		" " 5 ml.	S--69505	16355	13--650
2	2		" " 1 ml.	S--69505	16355	13--650
6	4		Pipettes, Mohr, 10 ml., grad. to 1/10 ml.	S--69555	16325	13--665
2	1		Rings, iron, 4 in.	S--73045	18005	14--050
2	1		" " 3 in.	S--73045	18005	14--050
4	2		Supports, iron, large.	S--78305	19005	14--670
1	1		Spatula, stainless steel, 100 mm.	S--75245	18755	14--365

* For activated sludge plants only.
† From Engineering Manual, War Dept., Corps of Engrs., Jan. 1943.

SEWAGE TREATMENT - LABORATORY EQUIPMENT†-2

RECOMMENDED LABORATORY EQUIPMENT FOR SEWAGE TREATMENT PLANTS

QUANTITY Type of Plant A & B	C	D	DESCRIPTION	CATALOGUE NUMBERS E. H. Sargent & Co.	Central Scientific Co.	Fisher Scientific Co.
1	1		Spoon, horn, 150 mm.	S--75175	18775	14--425
2	1		Thermometers: 10°C. to 110°C.	S--80005	19240	14--985
1	1		" 10°C. to 250°C.	S--80005	19240	14--985
2	1	1	" 10°F. to 220°F.	S--80015	19280	14--990
2	2		Crucible holder, Walter	S--24475	18110	8--285
4	2		Graduated cylinders, double grad., 1 liter	S--24685	16105	8--555
1	1		" " " " 500 ml.	S--24685	16105	8--555
1	1		" " " " 250 ml.	S--24685	16105	8--555
2	2		" " " " 100 ml.	S--24685	16105	8--555
1	1	1	Low form " " " 100 ml.	S--24765		
1	1		Desiccator, Schiebler, with plates, 250 mm.	S--25015	14560	8--600
6			Dishes, evaporating, Coors, porcelain, 150 ml.	S--25505	18575-2	8--690-C
2	1		Files, triangular tapered, 4"	S--32225	88325	9--725
12	6		Filter paper, No. 500 per pkg. of 100-9 cm.	S--32915	13250	9--795
2			" " " " " " " 100-12.5 cm.	S--32915	13250	9--795
6	3		Flasks, Erlenmeyer, Pyrex, 500 ml.	S--34355	14905	10--040
6	3		Flasks, 250 ml.	S--34355	14905	10--040
2	1		Flasks, filtering, side tubulature, 500 ml.	S--34375	14985	10--175
2	1		Flasks, volumetric, 1 liter	S--34805	16220	10--200
1	1		" " 500 ml.	S--34805	16220	10--200
2	1		" " 250 ml.	S--34805	16220	10--200
4	2		" " 200 ml.	S--34805	16220	10--200
2	1		" " 100 ml.	S--34805	16220	10--200
1	1		Flask, volumetric, 200 ml., large mouth for D.O.	S--34995	16290	10--240
1	1		Filter, Sedgewick, rafter graduated for B.O.D. dilution	S--84015	29030	15--400
1	1		Plate, spot, size 00 plate, porcelain	S--70025	18600	13--745
				S--69985	18600	13--745
2	1		Tongs, crucible, lock joint, $9\frac{1}{2}$"	S--82205	19620	15--185
1	1		" " " " 14"	S--82215	19620	15--185
2	1		Triangle, Nichrome 2"	S--82445	19705	15--260
2	1		Wire gauze, chromel 4" x 4"	S--85315	19960	15--585
20	10		Rubber tubing, medium wall pure gum per ft. $\frac{1}{4}$"	S--73505	18200	14--155
10	10		" " " " " " " " 3/8"	S--73505	18200	14--155
10	10		Rubber tubing, vacuum, $\frac{1}{4}$"	S--73535	18204	14--175
1	1		Filter pump, Richards, size A 3/8"	S--33565	13205	9--965
6	4		Bottles, dropping 30 ml.	S--8745	10535	2--980
1	1		Funnel support, 4 place	S--78815	19035	14--740
1	1		Brush, test tube, med.	S--9995	10972	3--590
1	1		" flask, size B	S--9965	10985	3--570
1	1		Mortar and pestle, porcelain, 100 mm.	S--62235	17380	12--960
6	3		Bottles, 5 gal.	S--8435	10310	2--885
1	1		Still-water, Stokes gas heated	S--27645	12805	9--055
1	1	1	Chlorine testing set	S--83825	29255	
12	6		Automobile radiator hose for water seals, per ft.			
8	6	3	Milk kettles, ivory enameled, seamless 4 qt. cap. (for sample storage)			
2			Beakers, Pyrex, 2 liter	S--4675	14265	2--540
2	2		" " 1 liter	S--4675	14265	2--540
2			" " 600 ml.	S--4675	14265	2--540
4	6		" " 400 ml.	S--4675	14265	2--540
4	6		" " 250 ml.	S--4675	14265	2--540
2			" " 50 ml.	S--4675	14265	2--540

† From Engineering Manual, War Dept., Corps of Engrs., Jan. 1943

SEWAGE TREATMENT - LABORATORY EQUIPMENT†-3

RECOMMENDED LABORATORY EQUIPMENT FOR SEWAGE TREATMENT PLANTS

QUANITY Type of Plant A & B	C D	DESCRIPTION	CATALOGUE NUMBERS E. H. Sargent & Co.	Central Scientific Co.	Fisher Scientific Co.
½		Watch glasses, 115 mm. 1 doz.	S--83605	15850	2--610
		Bottles, glass-stoppered, flint glass, mach. made:			
12	6	32 oz.	S--8345	10430	2--915
6	3	16 oz.	S--8345	10430	2--915
72	24	8 oz.	S--8345	10430	2--915
36	36	4 oz.	S--8345	10430	2--915
2	1	Bottle washing, Pyrex, 1000 ml.	S--9365	10710	3--395
2	1	Burettes, Geissler, blue line, 50 ml.	S--10635	15925--C	3--700
2	1	Burners, Tirril with stabilizer	S--12295	11025--C	3--960
2	1	Clamps, burette, spring closing	S--19045	12120	5--770
2/3	1/3	" pinch, 1 doz.	S--19045	12180	5--850
3	2	Stoppers, rubber, assorted sizes, solid, per lb., $1.00	S--73305	18150	14--130
1	1	Cork borer, brass set 1 to 6	S--23175	12460--B	7--845
12	6	Crucibles, Coors, size 1, wide form	S--23665	18535	7--955
12	6	" Gooch, size 3, 0.7 mm., perforation, Coors porcelain	S--24315	18565	8--195

RECOMMENDED CHEMICALS FOR SEWAGE TREATMENT PLANTS

QUANTITY Type of Plant A & B	C	D	ITEM
18 lb.	9 lb.		Sulphuric acid, C. P.
18 lb.	9 lb.		Sulphuric acid, Tech.
6 lb.			Hydrochloric acid
100 gm.	100 gm.		Sodium azide*
1 lb.	1 lb.		Sodium bicarbonate
1 lb.			Sodium carbonate, anhyd., C.P.
5 lb.	5 lb.		Sodium hydroxide pellets, U.S.P.
1 lb.	1 lb.		Sodium thiosulphate, cryst.
1 lb.	1 lb.		Potassium iodide, C.P.
1 oz.	1 oz.		Potassium bis-iodate, C.P.
5 lb.	5 lb.		Potassium bichromate, Tech.
5 lb.	5 lb.		Manganous sulphate, C.P.
½ lb.	¼ lb.		Potato starch
1 oz.	1 oz.		Methylene blue, U.S.P.
½ lb.	½ lb.		Asbestos, med. fiber, acid washed
5 lb.			Ferric chloride, C. P. Lump
5 lb.			Copper sulphate, cryst., Tech.
½ lb.	¼ lb.		Chloroform, U.S.P.
100 gm.			Orthotolidine
100 ml.			Phenolphthalein indicator
100 ml.			Methyl orange indicator
Obtain in field, Ampules			Calcium hypochlorite
5 lb.	5 lb.		Calcium chloride, anhyd.

* For secondary treatment plants only.
† From Engineering Manual, War Dept., Corps of Engrs., Jan. 1943.

SEWAGE TREATMENT - TOOL LIST FOR PLANTS†

TOOL LIST FOR SEWAGE TREATMENT PLANTS

Minimum Requirements for Class A, B, and C Plants

Quantity	Description	Catalogue No. *	
1	Wrenches, pipe: 8"	258	ZAO or equal
1	" " 12"	2512	ZAO " "
2	" " 18"	2518	ZAO " "
1	" " 24"	2524	ZAO " "
1	Wrenches, open double end set of 9, $\frac{1}{4}$" to 1"	P 725	ZAO Series or equal
1	Wrenches, socket, hex, set of 10 and handle, 7/16" to 1"	P 21	ZAO " "
1	Wrench, crescent adjustable, 10"	710	ZA1 " "
1	Vise, combination jaw and pipe, swivel base	A 204$\frac{1}{2}$	ZA2 " "
1	Hammer: blacksmith, 2$\frac{1}{2}$ lb.	0272	ZAO " "
1	Ball pein #2	252	ZAO " "
1	Claw #1	211	ZAO " "
1	Pliers, combination, 8"	26	GZA1 " "
1	Screw driver, 6"	26	ZAO " "
2	File, 10" mill bastard	3	ZA3 " "
1	Cold chisel: $\frac{1}{2}$"	200	ZAO " "
1	1" extra long	205	ZAO " "
1	Hacksaw	1027	ZA1 " "
1	Hacksaw blades, doz.	1412	FLZAO " "
1	Wrecking bar, 24"	95	ZAO " "
1	Hand saw, 26", 8 point	80	ZA2-D8 " "

* H. Channon Co. Cat. #166, Chicago, Ill.

† From Engineering Manual, War Dept., Corps of Engrs., Jan. 1943

WASTE DISPOSAL — SANITARY FILL

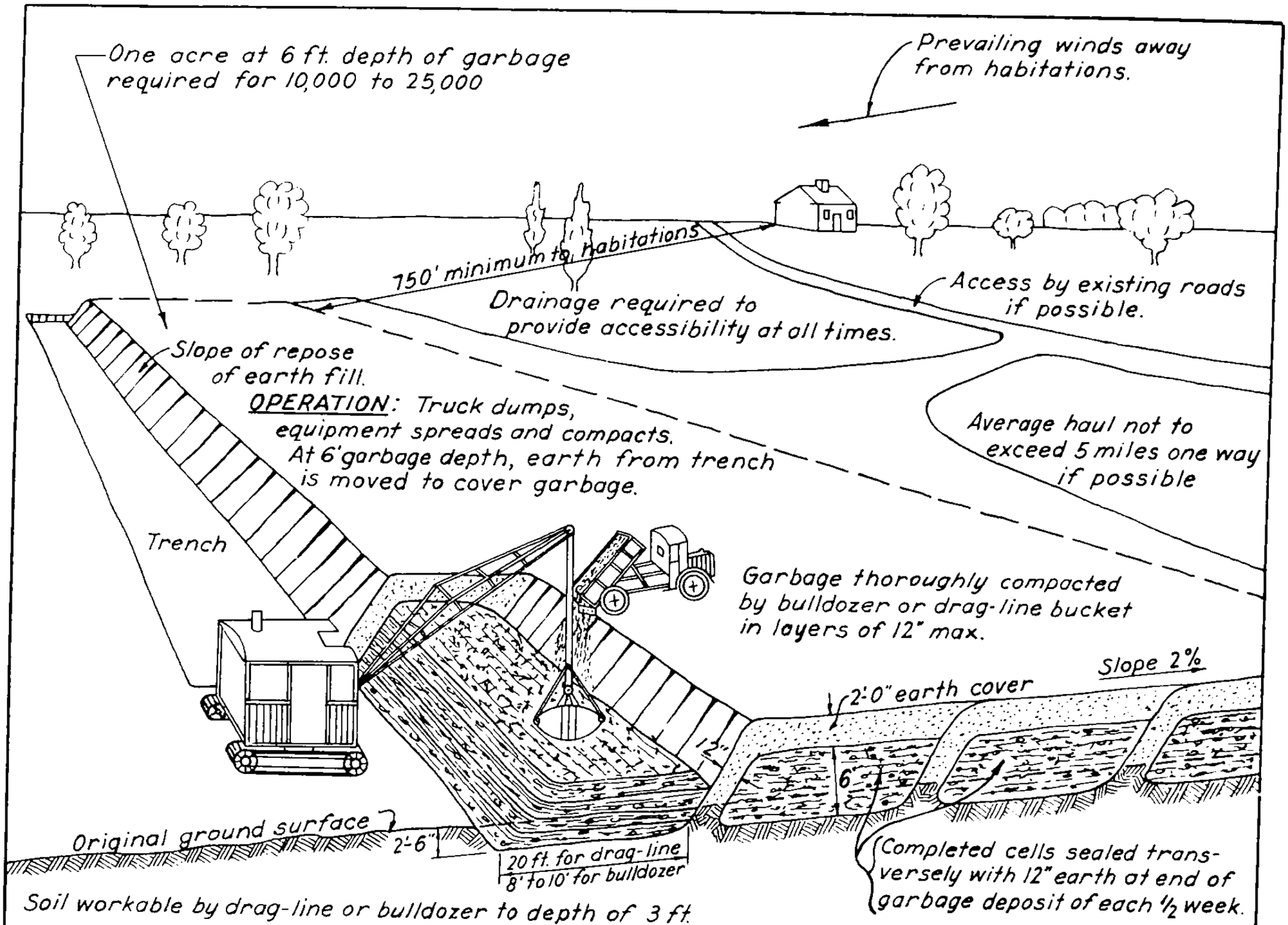


FIG. A — SANITARY FILL CONSTRUCTION

TABLE B — EQUIPMENT REQUIRED

POPULATION	TYPE	BOOM	BUCKET
Under 20,000	Bulldozer	—	1 Cu. Yd.
20,000 to 50,000	Drag-line	30 ft.	½ Cu. Yd.
Over 50,000	" "	40 ft.	¾ Cu. Yd.

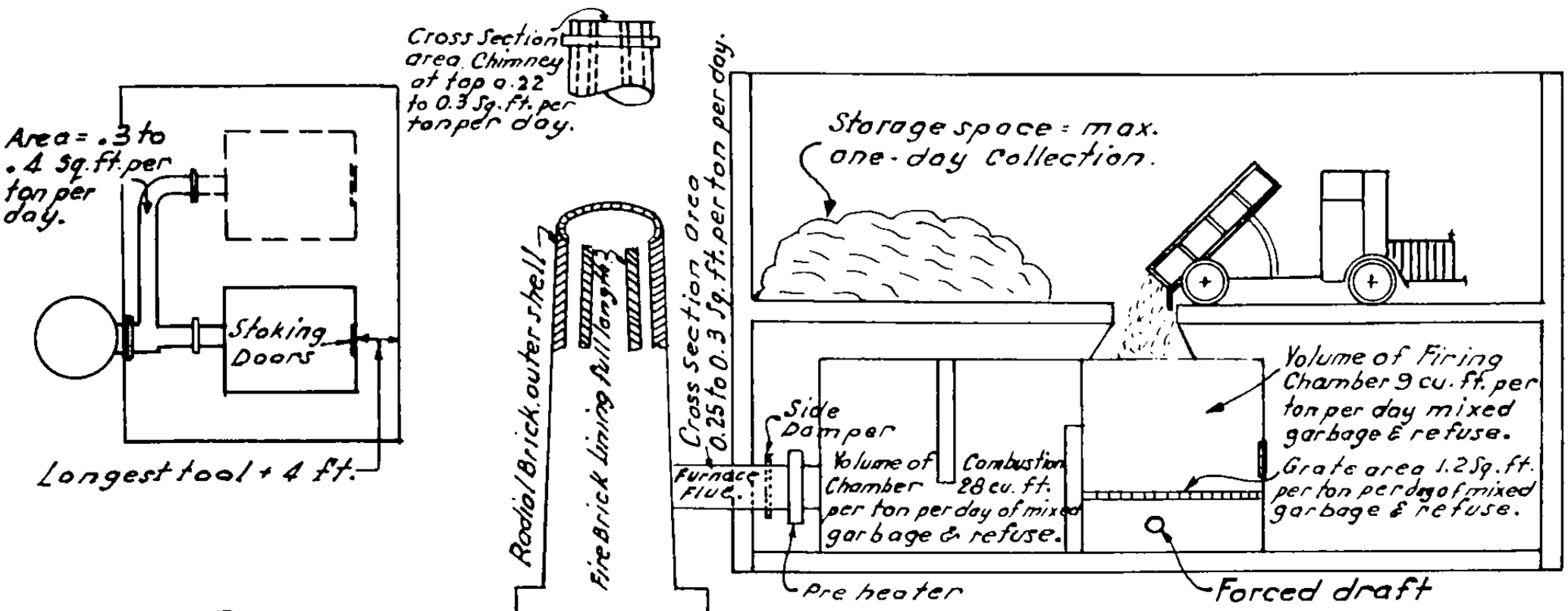
TABLE C — QUANTITIES OF REFUSE IN POUNDS PER CAPITA PER YEAR*

	GARBAGE	RUBBISH
According to economical conditions, locality, climate and method of collection.	100 to 450	30 to 150
Average for large cities.	180	102
NOTE: Peak for short periods = 140% to 200% times average.		

Average unit weights:* Garbage = 40 lbs. per cu. ft.; rubbish = 7.41 lbs. per cu. ft.

* Data based on American Civil Eng. Handbook by Merriman & Wiggin.

WASTE DISPOSAL – INCINERATION *



PLAN SECTION

GARBAGE & REFUSE PRODUCTION.

Each 1000 population produces approx. 1 ton of mixed garbage and refuse per day (including stores, restaurants, hotels, etc.); general wide variation depending on efficiency of collection service, etc.
High-Class residential section alone produces 1 lb. per capita per day.
Poor " " " " " 3/4 lb. " " " "
Month of February produces 5% of annual total tonnage.
" " August " 11% " " " "

BASIC ELEMENTS OF DESIGN.

Average moisture content of mixed garbage & refuse = 55% by weight.
Average content of combustible material = 45% by weight, of which 5% is average residual ash.
These percentages may vary 50% above or below depending on character of community; a wealthy residential community will produce higher % of combustible material.
Mixed combustible material will produce 7000 to 8000 B.T.U. per pound.
Forced draft required per pound of combustible material = 19 lbs. of air.
Max. H. P. required per ton of combustible material for forced draft = 0.30 H. P.
Optimum temperature of furnaces = 1250° F.
Preliminary drying area or storage hoppers should have capacity to accommodate a full day's (8 hr.) collections.
Clearance in front of stoking doors should be 4 ft. greater than length of longest stoking tool.
Customary chimney ht. = 100 ft. ±; 50' min. Above surrounding bldgs. but not too conspicuous.

EXAMPLE – COMMUNITY OF 50,000.

1. Total waste production @ 2# per capita per day = 2 x 50,000 = 100,000 lbs. daily
2. Average moisture content = 55% x 100,000# = 55,000 lbs. water
3. Average water per hour (8 hr. incinerator operation) = $\frac{55,000}{8}$ = 6,875 lbs. per hour
4. Average combustible content = 40% x 100,000# = 40,000 lbs. combustible
5. Average combustible per hour (8 hour operation) = 5,000 lbs. per hour
6. Average ash content = 5% x 100,000# = 5,000 lbs. ash
7. Average ash per hour (8 hour operation) = 625 lbs. ash
8. Average wt. air reqd. @ 19 lbs. per lb. combustible) = 19 x 5000# = 95,000 lbs. per hour
9. Cu. ft. of air / min. required = 1/5 x 95,000 lbs. = 19,000 c.f.m.
10. Capacity (approximate) of blower = 19,000 c.f.m. less natural draft
11. Heat requirements (from 0°F. to 1250°F.) per hour.

a. to raise 6875 lbs. water to 212°F. = 212 x 6,875	=	1,457,000	B.T.U.
b. to evaporate 6875 lbs. water @ 212°F. = 971 x 6,875	=	6,685,000	"
c. to raise steam from 212°F. to 1250°F. = .48 x 1,038 x 6,875	=	3,425,000	"
d. to raise 95,000 lbs. air to 1250°F. = .25 x 95,000 x 1,250	=	29,687,000	"
e. to raise 625 lbs. ash to 1250°F. = .20 x 625 x 1250	=	156,000	"
f. to raise 5000 lbs. combustible to 1250°F. = .20 x 5,000 x 1,250	=	1,250,000	"
Total + 10% radiation losses	=	46,926,000	B.T.U.

12. Heat generated per hour
 a. 5,000 lbs. combustible @ 7,500 B.T.U. per lb. = 37,500,000
13. Heat to be supplied by fuel, 9,426,000 B.T.U.
14. Gallons oil per hr. @ 151,300 B.T.U. per gal. $\frac{9,426,000}{151,300}$ = 62.5 gals. oil per hr. max.

* By Fred J. Biele, C.E., Sanitary Engineer.

WATER SUPPLY — DEMANDS - 1

1. *FACTORS AFFECTING DEMAND* are population, per capita consumption, pressure, quality, cost, sewer facilities, climate, air conditioning and use of meters.
2. *INDUSTRIES* or other special large consumers to be carefully considered.
3. *EXTENSIONS OF SYSTEMS*: Field survey of pressures and consumption best guide to design.
4. *FUTURE*: Systems and extensions are generally designed for 30 years hence.
5. *CAPACITY* of system to be sufficient to deliver max. daily flow simultaneously with required fire flow (See Pg. 6-01). Fire flow generally governs design of distribution system.

TABLE A – AVERAGE DESIGN VALUES FOR MUNICIPAL WATER SYSTEMS.

TYPE OF TOWN	AVERAGE ANNUAL GALS. PER CAP. PER DAY.
Largely Residential.	60 – 75
Medium and Large Residential, Business, Commerce and Industry.	100

Based on well regulated and operated system, good plumbing and metering. Values include public uses, waste and miscellaneous.

TABLE B – FACTORS AFFECTING DEMAND.

FACTOR	EFFECT IN %
Pressure ±	± 10
Quality ±	± 5
Cost ∓	± 20
Absence of sewage facilities	– 10
Absence of meters	+20 to +100

Above table extremely approximate, to be used only preliminary to complete analysis & investigation.

TABLE C – FLUCTUATION OF DEMAND.

MAXIMUM DEMAND	% OF AVERAGE ANNUAL DEMAND
MONTHLY	110 - 125
DAILY	110 - 140
HOURLY: Without fire demand.	150 - 220
HOURLY: With fire demand.	200 - 500

TABLE D - COMMERCIAL WATER CONSUMPTION IN THE BORO. OF MANHATTAN, N.Y.C.

TYPE OF BUILDING	GALLONS PER DAY PER 1000 SQ. FT.
Hotels	600 – 1100
Office buildings	100 – 500
Department stores	100 – 400
Apartment hotels	200 – 400
Average	300

TABLE E - PLUMBING FIXTURES*
SEE FIG. C - Pg. 6-64 FOR FACTORS OF USAGE.

FIXTURE	EXCELLENT FLOW G.P.M.	PRESSURE AT OUTLET (FAUCET WIDE OPEN) P.S.I.
Lavatory faucets, single.	4	4
Bath tubs, faucets, single.	6	5
Combination bath tub faucets.	8	5
Sink faucets.	6	5
Shower heads.	6	3
Shower mixing valves.	6	30
Water closets, tank type.	5	5
Water closets, flush valves.	30	25
Garden hose & nozzle.	10	30 at hydrant

TABLE F – AVERAGE DESIGN VALUES FOR INSTITUTIONAL & PRIVATE SYSTEMS.

DESCRIPTION	GALS. PER CAP. PER DAY
Camps	25 - 40
Small dwellings, Farm houses, etc.	40 - 60
Large dwellings, Boarding Schools, etc.	75 - 100
Institutions (Except Hospitals).	75 - 125
Hospitals	150 - 250
Day schools	15
Day schools with showers	20
Factories	25

TABLE G – MISCELLANEOUS REQUIREMENTS.†

DOMESTIC FIXTURES.	GALLONS
Filling the ordinary lavatory.	1½
Filling the average bathtub.	30
Flushing water cabinet closet.	6
Shower bath.	30
LAWN FIXTURE.	**GALS. PER HR.**
½ inch hose with nozzle.	200
¾ inch hose with nozzle.	300
Lawn sprinkler	120
Continuous flowing drinking fountain.	3+
FARM ANIMALS.	**GALS. PER DAY**
Each cow or horse.	10
Each hog or sheep.	5
100 Chickens.	2½

* Data from Davis, Handbook of Applied Hydraulics, McGraw-Hill
† Data from Peerless Pump Co.

WATER SUPPLY - DEMANDS-2

FIRE REQUIREMENTS

TABLE A - FIRE FLOW & HYDRANT SPACING FOR PRINCIPLE MERCANTILE OR BUSINESS DISTRICTS FOR VILLAGES AND CITIES OF VARIOUS TOTAL POPULATIONS.*
(SEE NOTES BELOW FOR REQUIREMENTS FOR OTHER DISTRICTS)

POPULATION	REQUIRED FIRE FLOW AT ANY POINT GALS. PER MIN.	HOURS DURATION	AVERAGE AREA PER HYDRANT IN SQUARE FEET	
			ENGINE STREAMS	DIRECT HYDR. STREAMS
1,000	1,000	4	120,000	100,000
2,000	1,500	6		90,000
4,000	2,000	8	110,000	85,000
6,000	2,500	10		78,000
10,000	3,000	10	100,000	70,000
13,000	3,500	10		
17,000	4,000	10	90,000	55,000
22,000	4,500	10		
28,000	5,000	10	85,000	40,000
40,000	6,000	10	80,000	40,000
60,000	7,000	10	70,000	40,000
80,000	8,000	10	60,000	40,000
100,000	9,000	10	55,000	40,000
125,000	10,000	10	48,000	40,000
150,000	11,000	10	43,000	40,000
200,000	12,000	10	40,000	40,000

Populations over 200,000, an additional flow of 2,000 to 8,000 g.p.m. is required for a second 10 hour fire.

In Residential Districts:- The required fire flow depends upon the character and congestion of the buildings. Sections where buildings are small and of low height and with about 1/3 the lots in a block built upon require not less than 500 gallons a minute; with larger or higher buildings up to 1,000 gallons is required, and where the district is closely built or buildings approach the dimension of hotels or high value residences, 1,500 to 3,000 gallons is required, with up to 6,000 gallons in densely built sections of 3-Story buildings.

TABLE B — PRESSURE REQUIREMENTS AS RECOMMENDED BY THE NATIONAL BOARD OF FIRE UNDERWRITERS.

CONDITION	RESIDUAL † PRESSURE AT HYDRANT LBS. PER □"
PUMPING ENGINES	10 - 20
DIRECT FLOW FROM HYDRANTS	
1.- High value districts	75
2.- Districts where not more than 10 buildings exceed 3 stories and in closely built residential sections.	60
3.- Village mercantile districts where buildings do not exceed two stories and in thinly built residential sections.	50

† Residual pressure = pressure at hydrant when required flow is being delivered.

NOTE: A.W.W.A. recommends a normal pressure of 60 to 75 p.s.i. in a distribution system at all times.

HYDRANTS

1.- Common arrangement of hydrant is one 4½" connection for fire engine pumper, and two 2½" connections for direct hose connections.
2.- Connect hydrant to main line with pipe not less than 6" diameter, gated and located at street intersection with access from four directions.

TABLE C — METHODS FOR SUPPLYING PRESSURE FOR FIRE STREAMS.**

	METHOD	RECOMMENDED FOR USE
1.	Maintenance of sufficient pressure on the mains at all times for direct hydrant service for hose streams.	For villages not provided with full time fire depts. and mobile pumpers. Not usually economical for large communities.
2.	Use of emergency fire pumps to boost the pressure in the distribution system during fires.	For villages requiring higher pressures for fire fighting than are desirable for normal consumption and where there are no mobile pumpers.
3.	Use of mobile pumping engines which take suction from the hydrants.	For all communities large enough to maintain modern and well-trained fire departments.
4.	Use of a separate high-pressure distribution system for fire protection only.	In high value districts of large cities. Supplements main distribution system. Pressures used - 150-300 #/□"

* From National Board of Fire Underwriters.
** From Davis, Handbook of Applied Hydraulics, McGraw-Hill.

WATER SUPPLY - RAINFALL & RUNOFF F-1

PROCEDURE FOR OBTAINING RUNOFF DATA FOR A DRAINAGE AREA.

1. Use stream gage data if available. (Best source U.S. Geological Survey.) Supplement by records of stream gaged in same locality.
2. For general perspective See Fig. C & D, Pg. 6-06.
3. For approximations use Fig. A & B below and Table A & B, Pg. 6-03.
4. See Pg. 6-04 & 6-05 for reservoir storage.
5. For complete analytical analysis see Elements of Hydrology by A. F. Meyer (John Wiley & Sons) and River Discharge by Hoyt & Grover (John Wiley & Sons).

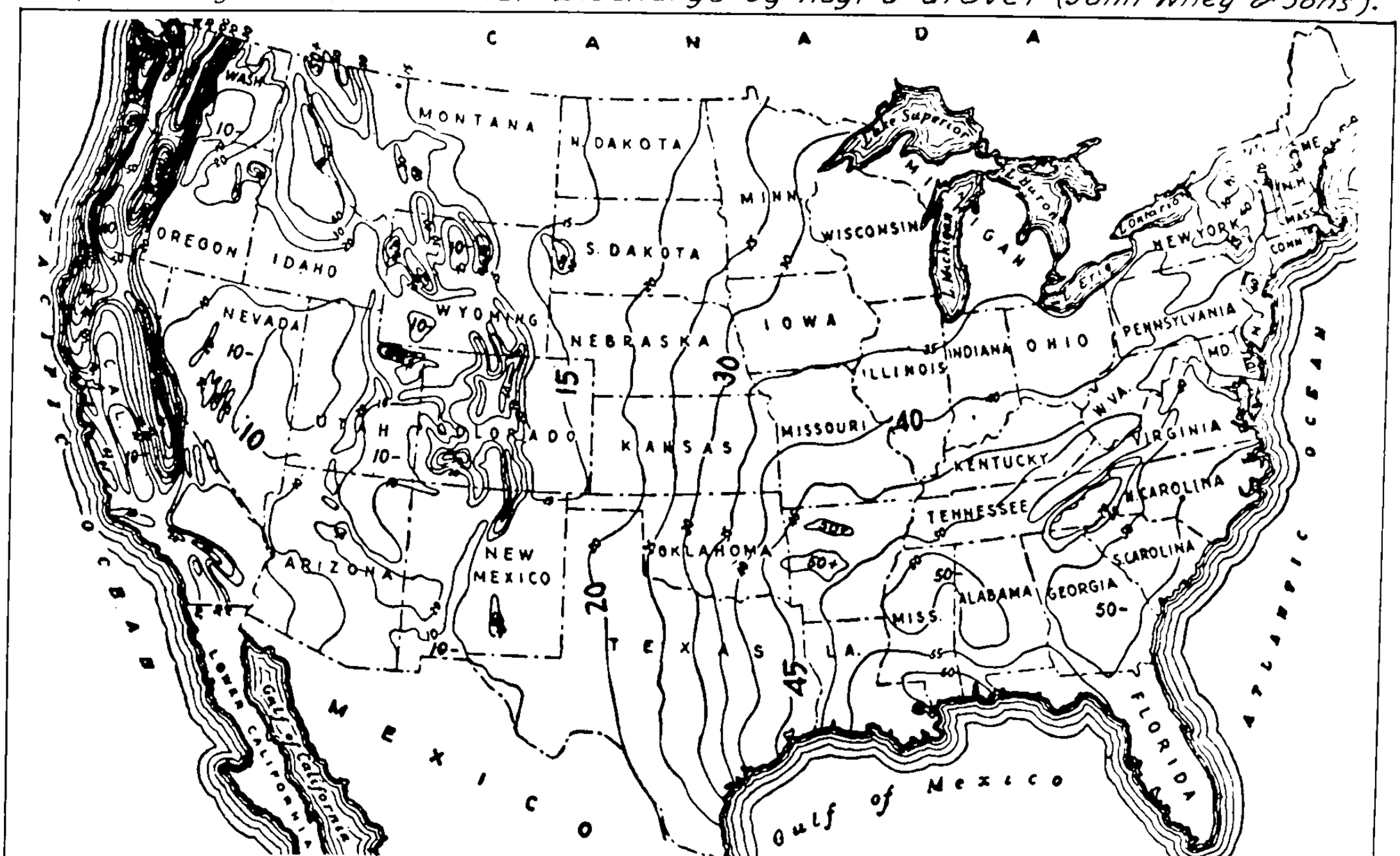


FIG. A - MEAN ANNUAL PRECIPITATION - INCHES PER YEAR.*

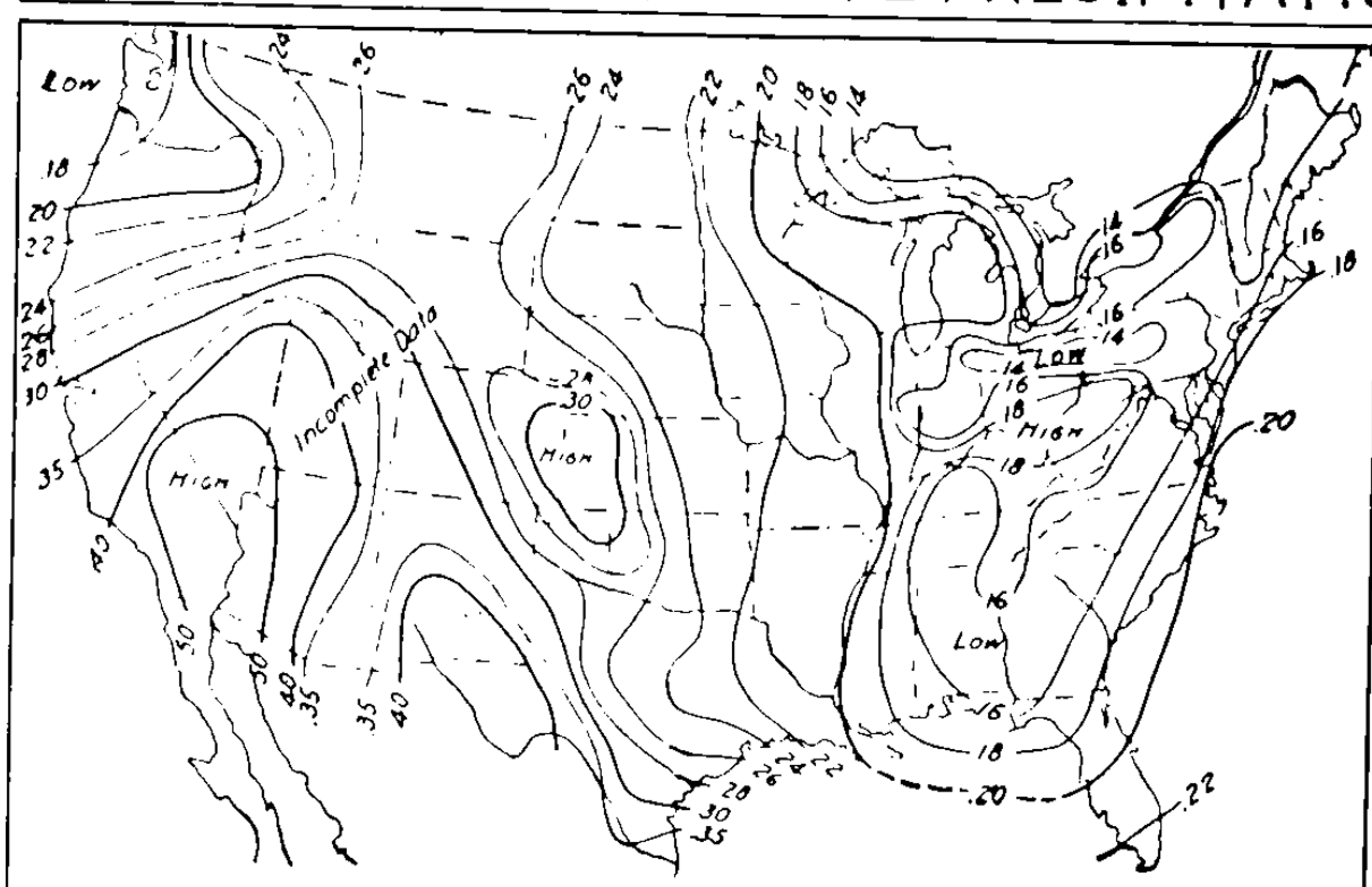


FIG. B - RAINFALL COEFFICIENTS (AFTER HAZEN).**

MINIMUM RAINFALL.

7 year min. rainfall = Value in Fig. A × (1.00 - Coefficient in Fig. B).
45 year min. rainfall = Value in Fig. A × (1.00 - 2 × Coefficient in Fig. B).

The minimum rainfall for a period of 30 to 40 years is recommended for municipal design.

* From Handbook of Culvert & Drainage Practice by Armco Mfrs. Assn. (Based on U.S. Weather Bureau records).
** From Public Water Supplies by F. E. Turneaure & H. L. Russell.

WATER SUPPLY – RAINFALL & RUNOFF-2

TABLE A – ANNUAL RUNOFF FROM STREAM DRAINAGE BASINS.*

STREAM	LOCALITY	DRAINAGE AREA SQUARE MILES	PERIOD OF OBSERVATION	AVERAGE ANNUAL PRECIPIT. (INCHES)	AVERAGE ANNUAL RUNOFF (INCHES)
Kennebec River	Waterville, Maine	4,270	1893-1905	39.6	23.7
Cobbosseecontee River	Gardiner, Maine	240	1891-1905	42.2	17.4
Sudbury River	Massachusetts	75	1875-1932	44.3	21.2
Wachusett River	Massachusetts	109	1897-1932	45.0	23.7
Merrimac River	Lawrence, Mass.	4,461	1880-1934	41.6	20.1
Lake Cochituate	Cochituate, Mass.	18.9	1863-1900	47.1	20.3
Mystic Lake	Boston, Mass.	26.9	1878-95	44.1	20.0
Abbott Run	Rhode Island	27	1908-32	42.9	21.1
Nepaug River	Hartford, Conn.	32	1920-35	42.4	17.8
Pomperaug River	Bennetts Bridge, Conn.	89	1914-16	44.5	19.5
Hudson River	Mechanicville, N. Y.	4,500	1888-1901	44.2	23.3
Croton River	Croton Dam, N. Y.	375	1868-1932	47.7	23.4
Delaware River	Port Jervis, N. Y.	3,070	1902-1930	42.8	25.9
Delaware River	Trenton, N. J.	6,800	1897-1930	44.7	24.9
Neshaminy Creek	Forks, Pa.	139	1884-99	47.6	23.1
Perkiomen Creek	Frederick, Pa.	152	1884-99	48.0	23.6
Tohickon Creek	Point Pleasant, Pa.	102	1888-1911	48.9	26.1
Susquehanna River	Harrisburg, Pa.	28,030	1891-1905	39.4	21.1
Potomac River	Point of Rocks, Md.	9,650	1895-1905	36.8	14.2
James River	Cartersville, Va.	6,240	1899-1934	40.8	15.6
Do	Buchanan, Va.	2,060	1895-1905	41.2	16.9
Roanoke River	Roanoke, Va.	390	1897-1905	42.7	17.7
Shenandoah River	Millville, W. Va.	3,000	1895-1905	38.3	13.6
Ohio River	Wheeling, W. Va.	23,820	1884-1905	41.7	22.7
Miami River	Dayton, Ohio	2,525	25 yrs	37.1	11.9
Muskingum River	Dresden, Ohio	5,828	1888-95	39.7	13.1
Tennessee River	Chattanooga, Tenn.	21,400	1881-1934	50.3	24.2
Chattahoochee River	West Point, Ga.	3,550	1896-1934	54.6	22.3
Tombigbee River	Columbus, Miss.	4,440	1901-9	49.2	17.1
Rock River	Rockton, Ill.	6,290	1904-8	33.9	10.0
Wisconsin River	Rhinelander, Wis.	1,110	1909-14	29.6	15.1
Mississippi River	Minneapolis, Minn.	19,500	1897-1913	27.4	5.3
Little Fork River	Little Fork, Minn.	1,720	1909-13	23.9	5.1
Root River	Houston, Minn.	1,560	1908-13	31.4	5.2
Ottertail River	Fergus Falls, Minn.	1,310	1908-13	23.0	2.6
St. Croix River	St. Croix Falls, Minn.	5,930	1902-12	30.0	9.6
Red River	Grand Forks, N. Dak.	25,500	1882-1934	20.9	1.2
Mississippi River	Keokuk, Iowa	119,000	1878-1934	29.5	7.0
Ralston Creek	Iowa City, Iowa	3	1925-35	33.1	6.8
Drainage basin A	Wagonwheel Gap, Colo.	.35	1911-26	21.1	6.4
Drainage basin B	Do	.31	1911-26	21.0	6.7
Colorado River	Austin, Tex.	37,000	1900-9	26.9	7
South Fork of Coquille River	Powers, Oreg.	168	1917-26	96.0	63.5
Rogue River	Raygold, Oreg.	2,020	1906-28	43.6	22.6
Pilarcitos and San Andreas Creeks	San Andreas Reservoir, Calif.	12	1869-1903	45.0	18.0
South Fork of Yuba River	Lake Spaulding, Calif.	124.5	1907-39	60.60	47.4

TABLE B – COMPARISON OF MEAN & MINIMUM ANNUAL RUNOFFS.**

RIVER LOCALITY	YEARS OF RECORD	AREA DRAINED SQ. MILES	MEAN ANNUAL FLOW IN INCHES THROUGH SEPT. 41.	YEAR OF MIN. FLOW	MIN. ANNUAL FLOW IN INCHES	PERCENTAGE OF AVERAGE
Merrimack, N.H.	37	1,507	25.0	1931	16.9	68
Quinebaug, Conn.	24	711	23.8	1930	11.4	48
Sacandaga, N.Y.	30	491	30.7	1934	20.0	65
Genesee, N.Y.	34	1,017	15.9	1934	10.4	65
So. Branch Raritan, N.J.	22	65	23.5	1932	12.0	51
Susquehanna, Pa.	52	24,100	19.3	1931	11.4	59
Potomac, Md.	46	9,650	13.3	1934	6.8	51
James, Va.	42	6,242	15.7	1931	7.8	50
Santee, S.C.	34	14,800	17.0	1927	9.0	53
Chattahoochee, Ga.	44	3,550	21.9	1914	11.0	50
Tombigbee, Miss.	25	4,490	17.5	1904	5.1	29
Mad, Ohio.	26	485	14.1	1934	6.1	43
Cumberland, Ky.	28	4,890	21.0	1931	10.3	49
Tennessee, Tenn.	43	8,930	19.8	1941	10.0	50
Rock, Wis.	28	3,300	7.3	1934	2.4	33
Mississippi at St. Paul.	39	36,800	3.3	1934	0.72	22
Minnesota, Minn.	21	6,300	0.84	1934	0.0095	
Grand, Mo.	21	2,250	5.7	1938	0.78	14
Neosho, Kan.	20	4,830	5.4	1939	0.92	17
Trinity, Tex.	30	12,840	4.4	1909	0.44	10
Verde, Ariz.	41	6,230	1.7	1934	0.49	29
Humboldt, Nev.	34	5,010	0.87	1934	0.095	11
Sacramento, Calif.	48	9,300	16.3	1924	6.0	37
Kings, Calif.	47	1,694	18.7	1924	4.3	23
Spokane, Wash.	51	4,350	21.2	1930	10.4	49
Salmon, Idaho.	30	13,400	10.3	1931	5.9	57

Notes: Annual flows based on water year ending Sept. 30. Mean annual flow may have little significance in sub-humid, arid and semi-arid regions. Years of record not consecutive for all stations.

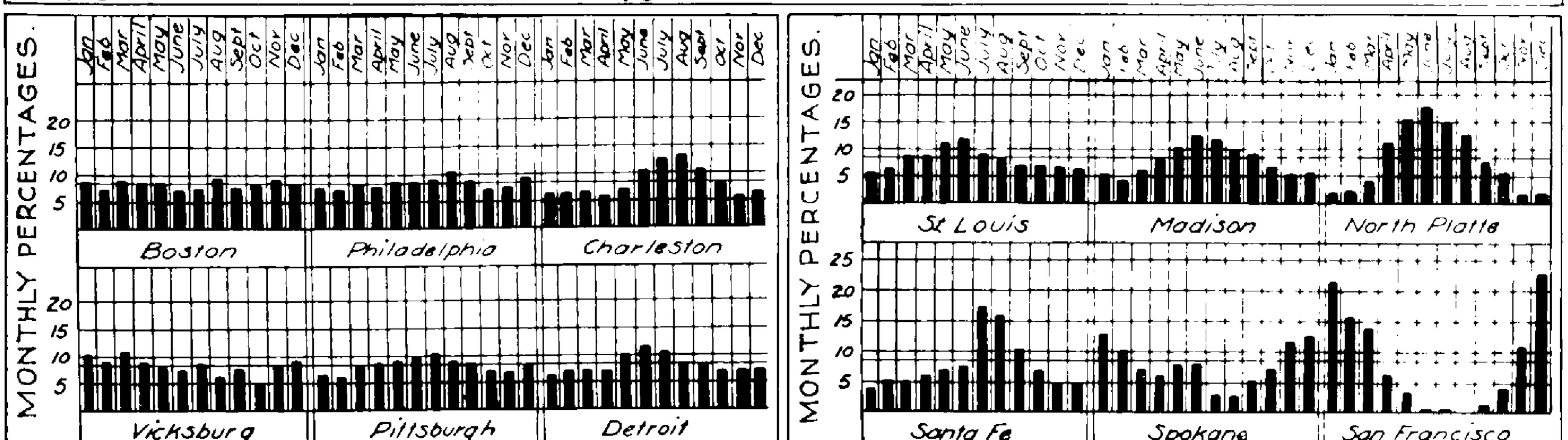


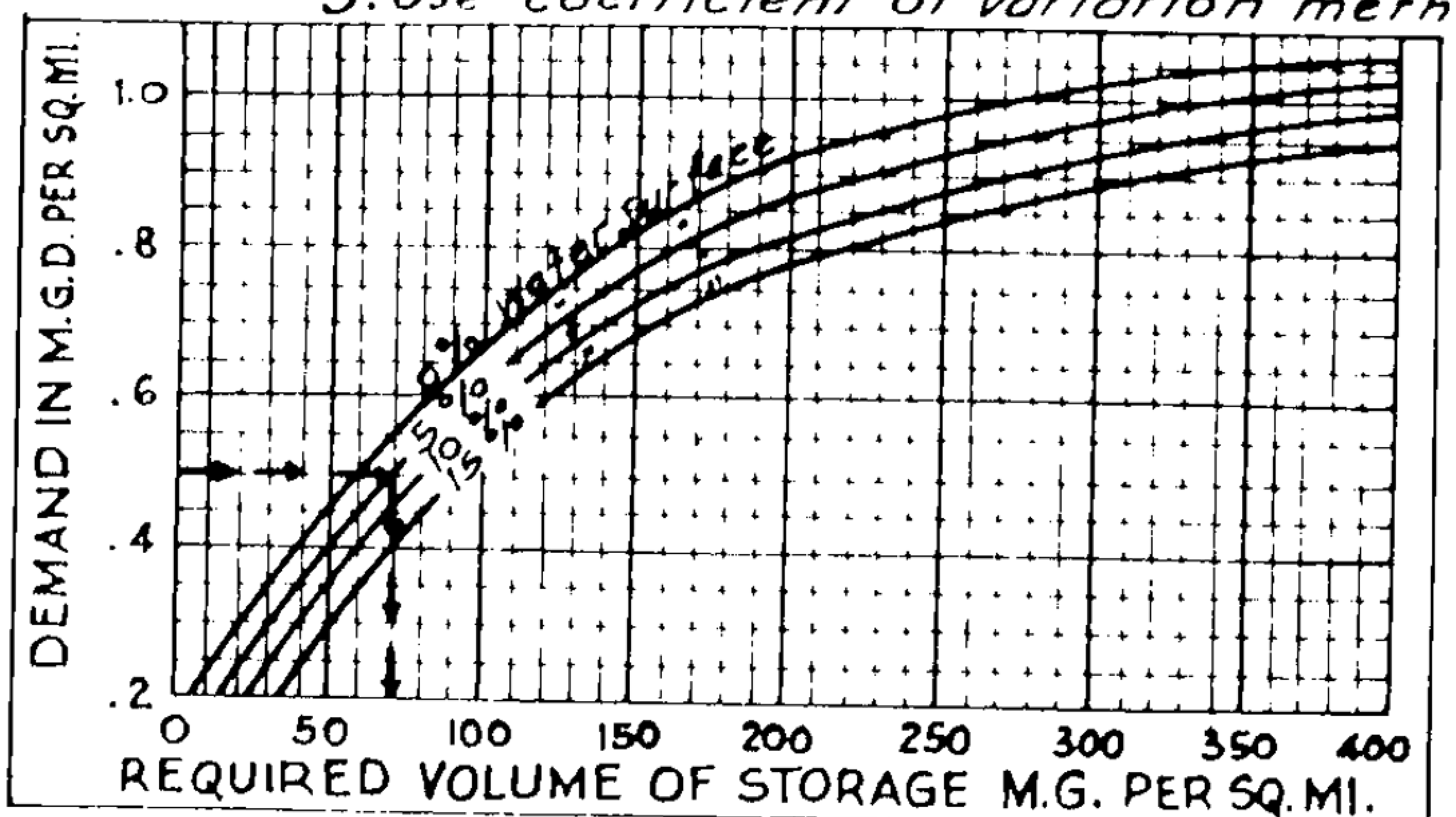
FIG. C – MONTHLY VARIATIONS IN RAINFALL.***

* Adapted from Physics of the Earth - IX. Hydrology Published by McGraw-Hill.
** Adapted from water-supply papers published by the Geological Survey U.S. Dept. of Interior.
*** Adapted from Public Water Supplies by F.E. Turneaure & H.L. Russell.

WATER SUPPLY - RESERVOIR STORAGE

PROCEDURE TO FIND REQUIRED VOLUME OF STORAGE FOR A GIVEN DEMAND.

1. Use Fig. A and example below for Maine, Mass., R.I., Conn. and New York States.
2. Use Mass diagram method, Pg. 6-05 if reasonably accurate monthly stream flow records are available for a 20 year or longer period of time.
3. Use "coefficient of variation" method for short record; Table B, C, D & explanation below.



EXAMPLE: Given: Location in Connecticut, demand of 5,000,000 gals. per day, a drainage area of 10 sq. miles and 5% water surface (% of water surface = area of all water surface when reservoir is full plus 40% area of underdrained swamps plus 30% of drained swamps divided by total drainage area).

Required: Volume of storage.

Solution: $\frac{5,000,000}{10 \text{ sq. mi.}} = .5$ m.g.d.

Enter Fig. A, at left, as indicated and required storage = 70 m.g.d. per sq. mile, 70 × 10 sq. mi. = 700,000,000 gals. Volume of storage required.

FIG. A - YIELD CURVES†. Composite diagram based on Abbott Run (R.I.), Sudbury and Manhan Rivers, Tillotson Brook, Wachusett reservoir (Mass.), Naugatuck River (Conn.), Croton River (N.Y.). Effects of New England drought of 1935 not included.

TABLE B - STORAGE RATIOS*

Reservoir not filling every year. Table usually applies to streams East of Mississippi, Oregon and Washington.

Per cent of mean flow used	Storage ratio c.v. = 0.20	c.v. = 0.22	c.v. = 0.24	c.v. = 0.26	c.v. = 0.28	c.v. = 0.30	c.v. = 0.35	c.v. = 0.40	c.v. = 0.45	Deduction for 30 days ground storage
95	1.21	1.33	1.46	1.60	1.74	1.90	2.30	2.70	3.10	0.078
90	0.85	0.92	1.00	1.09	1.20	1.31	1.60	1.88	2.20	0.074
85	0.66	0.71	0.77	0.83	0.91	1.00	1.23	1.47	1.70	0.070
80	0.54	0.57	0.61	0.66	0.71	0.78	0.97	1.19	1.39	0.066
75	0.45	0.47	0.50	0.53	0.57	0.62	0.77	0.95	1.13	0.062
70	0.39	0.40	0.41	0.44	0.47	0.50	0.62	0.76	0.92	0.058
65	0.35	0.35	0.35	0.37	0.39	0.41	0.50	0.61	0.74	0.053
60	0.31	0.31	0.31	0.32	0.33	0.34	0.40	0.49	0.60	0.049
55	0.27	0.27	0.27	0.27	0.28	0.28	0.33	0.39	0.49	0.045
50	0.23	0.23	0.23	0.23	0.23	0.24	0.26	0.32	0.39	0.041

TABLE C - STORAGE RATIOS*

Reservoir not filling every year. Table usually applies to streams West of Mississippi except Oregon & Washington.

Per cent of mean flow used	Storage ratio c.v. = 0.50	c.v. = 0.60	c.v. = 0.70	c.v. = 0.80	c.v. = 0.90	c.v. = 1.00	c.v. = 1.10	c.v. = 1.20	c.v. = 1.50
90	3.00	3.80	4.70	5.60	6.40				
85	2.30	3.00	3.70	4.50	5.30	6.10	7.00		
80	1.85	2.40	3.10	3.70	4.40	5.10	5.90	6.70	9.30
75	1.55	2.00	2.60	3.15	3.70	4.40	5.00	5.70	8.10
70	1.28	1.70	2.20	2.70	3.20	3.80	4.40	5.00	7.20
65	1.05	1.44	1.85	2.30	2.85	3.40	3.90	4.50	6.50
60	0.89	1.21	1.60	2.00	2.50	3.00	3.50	4.00	6.00
55	0.74	1.02	1.35	1.75	2.20	2.65	3.10	3.60	5.50
50	0.61	0.86	1.15	1.50	1.90	2.35	2.80	3.25	5.00
45	0.51	0.72	0.98	1.30	1.70	2.10	2.50	2.90	4.40
40	0.42	0.61	0.84	1.12	1.45	1.80	2.15	2.50	3.80
35	0.34	0.51	0.72	0.96	1.22	1.50	1.80	2.15	3.30
30	0.27	0.42	0.61	0.80	1.00	1.25	1.50	1.80	2.75

TABLE D - STORAGE RATIOS* See Note 3 at right.

Per cent of mean flow used	Storage ratio: Impervious soils No ground storage	Average soils 30 days' ground storage	Deep gravel and sand 60 days' ground storage	Greatest natural storage 90 days' ground storage
50	0.229	0.188	0.147	0.106
45	0.192	0.155	0.118	0.081
40	0.159	0.126	0.093	0.060
35	0.128	0.099	0.070	0.042
30	0.098	0.073	0.049	0.024
25	0.072	0.052	0.031	0.010
20	0.048	0.032	0.015	0
15	0.029	0.017	0.004	0
10	0.014	0.006	0	0

"COEFFICIENT OF VARIATION" METHOD.

1. Compute the "Coefficient of Variation" - C.V.

$$C.V. = \frac{1}{Q_m} \times \sqrt{\frac{(\text{numerical diff. of } Q_m \text{ \& } Q_1)^2 + (\text{num. diff. of } Q_m \text{ \& } Q_2)^2 + \text{etc.}}{n-1}}$$

in which Q_1, Q_2, Q_3, etc = total runoff in years 1, 2, 3 etc. (from local data).

n = number of years; $Q_m = \frac{Q_1 + Q_2 + Q_3, \text{etc.}}{n}$

Minimum C.V. to be used = .20.

2. Use Tables B and C as explained below.

EXAMPLE: Given: Location in North Carolina, demand 35 m.g.d., 48 sq. miles mountainous country (little ground storage), mean annual runoff = 25 in., C.V. = .20.

Required: Total volume of storage.

Solution: Total mean annual runoff = 48 × 25 × 17.39 (a constant to convert in. per sq. mi. to m.g. per year) = 20,868 m.g. per year or 57.1 m.g.d. The % of mean flow used = 35/57.1 = 61%. Use Table B and interpolate to find storage ratio = 0.318. Required storage = 0.318 × 20,868 = 6636 m.g. Add evaporation losses (Use Fig. A Pg. 6-06) to find total volume of storage required.

3. Use Table D if (1) the % of mean flow used is less than 50%, (2) C.V. from .20 to .25, (3) location is North of Potomac and East of Alleghenies.

GROUND STORAGE.

Table D shows effects of underlying soils on ground storage if per cent of mean flow used varies from 50% to 10%; Table B shows effects from 95% to 50%. These effects (reductions) can be applied to any storage ratio found in Table B or C.

EXAMPLE: Given: Drainage area of deep gravel and sand; storage ratio = .84.

Required: Corrected storage ratio for ground storage.

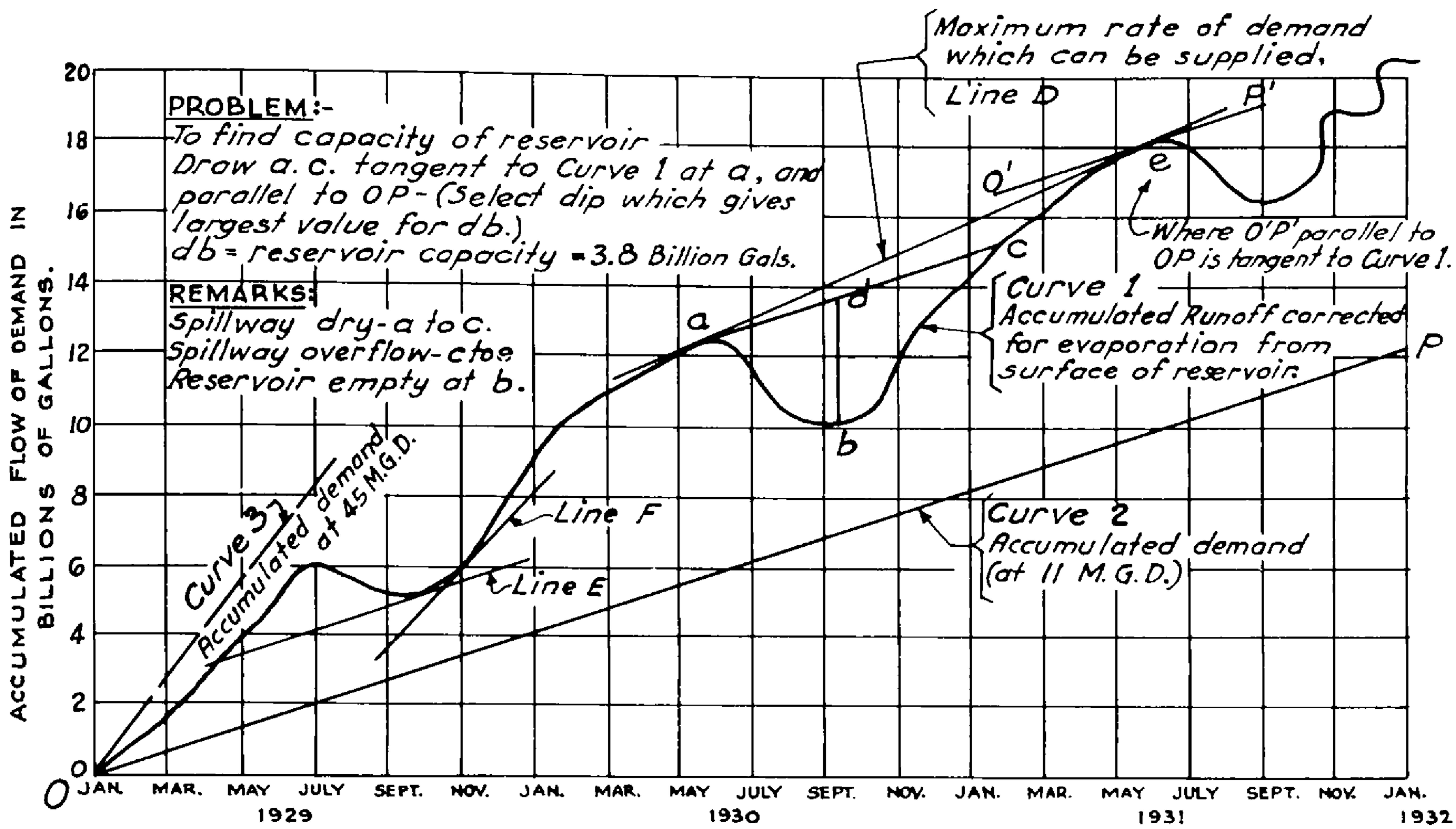
Solution: In Table D, at left, opposite 45%. Subtract .118 from .192 = .074, subtract .074 from .84 to get storage ratio corrected for ground storage.

It is common practice to disregard the effect of ground water in decreasing the required storage; the presence of ground water then becomes a factor of safety.

* Data from American Civil Engineers' Handbook by Merriman & Wiggin.

† Adapted from Flinn, Weston & Bogert, Waterworks Handbook, McGraw-Hill.

WATER SUPPLY - MASS DIAGRAM



NOTES:-*

1. *Impounding reservoir is required when the demand for water is greater than the minimum rate of flow in the stream from which the water is taken. The capacity of the impounding reservoir needed to supply the demand and other data can be determined by the study of mass diagrams of the demand and runoff for the years of minimum flow.*
2. *Curve 1.- The ordinates represent the total accumulated runoff from the start of observations to the time of the corresponding abscissas, less the sum of the accumulated evaporation from the reservoir and other reservoir losses such as leakage and percolation.*
3. *Curve 2.- Demand is assumed to be at constant rate.*
4. *The greatest rate of demand which can be supplied by the stream is represented by the slope of the line, above the Curve 1, which is tangent to it at two or more points but does not intersect Curve 1 at any point. This is shown as Line D on the figure and represents a rate of 15 million gallons per day.*
5. *If the demand is so great that the reservoir will never fill, a line drawn tangent to and below the runoff curve and parallel to the demand curve will not intersect the runoff curve to the left of the point of tangency. Line E shows that the reservoir will fill for Curve 2. Line F shows that the reservoir will not fill for Curve 3.*

*Adapted from Urquhart, Civil Engineering Handbook, Mc Graw-Hill.

WATER SUPPLY — EVAPORATION

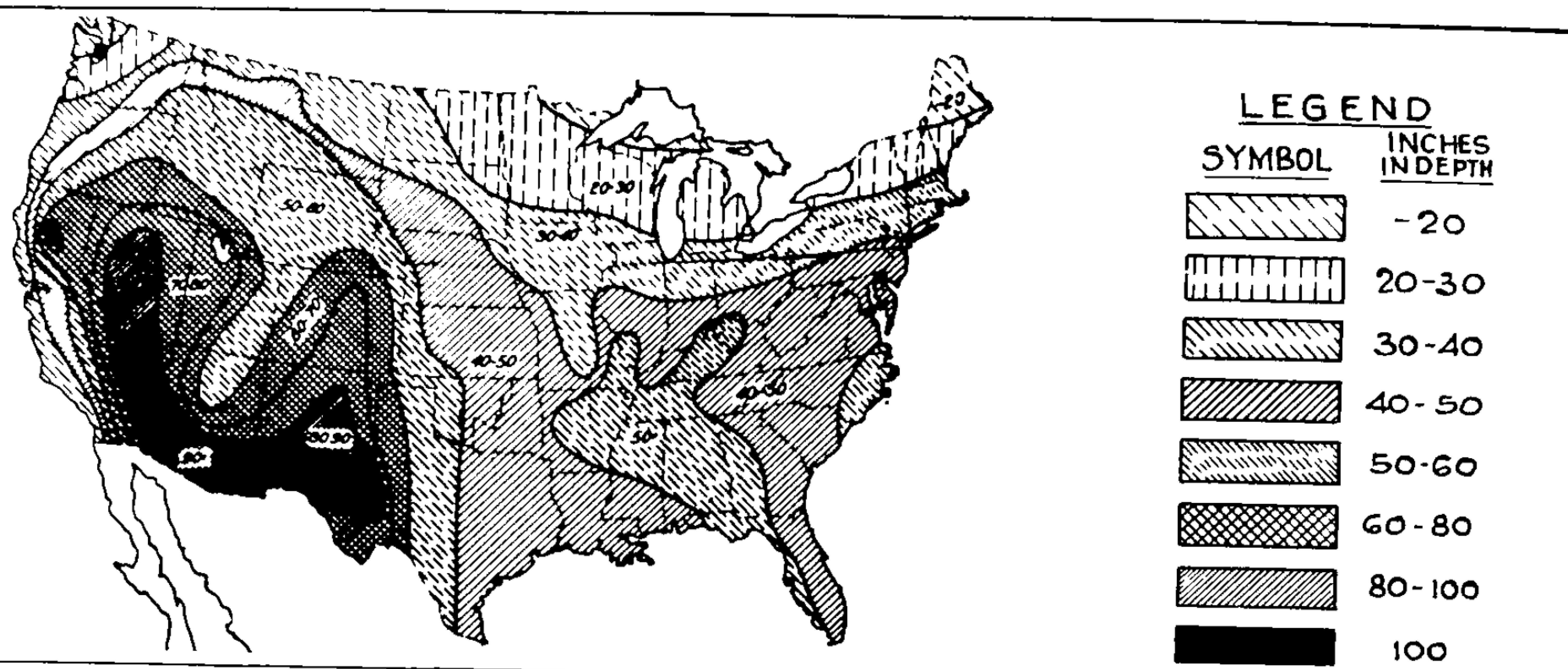


FIG. A - ANNUAL EVAPORATION FROM WATER SURFACE. *

TABLE B - RECORDED EVAPORATION FROM RESERVOIR SURFACES**

Station	Elevation, feet	Years	Temperature of air, degrees Fahrenheit	Wind velocity: Nearby U.S. Weather Bureau Station: Height, feet	Wind velocity: Nearby U.S. Weather Bureau Station: Velocity, miles per hour	Wind velocity: At the pan, miles per hour	Relative humidity, per cent	Reservoir surface evaporation, inches: April to September	Reservoir surface evaporation, inches: Annual	Reservoir surface evaporation, inches: Maximum per month	Percentage range of annual evaporation	Coefficient for pan
United States												
Ithaca, N.Y.	800	1918 to 1930	47	100	9.1	1.8	78	17.11	22.54	4.17	90 to 114	0.69
Washington, D.C.	280	1915 to 1917	54	85	6.5	2.3	69	23.52	34.53	4.87	97 to 103	0.69
Chapel Hill, N.C.	500	1921 to 1930	61	...	....	1.1	69	20.03	28.56	4.71	93 to 109	0.69
Madison, Wis.	800	1906 to 1911	46	78	10.0	..	75	12.91	19.82	3.04	97 to 102	0.83
Columbus, Ohio	763	1918 to 1930	52	230	10.7	2.0	74	19.21	26.81	4.94	89 to 108	0.69
Columbus, Mo.	750	1910 to 1927	54	84	8.0	1.5	71	20.28	28.13	5.31	88 to 114	0.60
Grand Forks, N.D.	820	1905 to 1920	38	58	9.8	...	79	21.72	27.07	5.82	90 to 117	0.83
Rapid City, S.D.	3,240	1916 to 1921	46	...	....	2.0	58	25.61	36.43	7.02	92 to 112	0.69
Lincoln, Neb.	1,250	1917 to 1930	51	81	10.0	4.1	69	32.06	42.04	9.92	87 to 118	0.69
Mitchell, Neb.	4,080	1911 to 1929	47	...	....	7.0	.	34.17	41.78	9.28	83 to 118	0.44
Lawrence, Kan.	825	1916 to 1919	55	...	....	4.4	..	31.25	44.80	7.62	....	0.69
Manhattan, Kan.	1,010	1924 to 1920	54	...		3.4	..	30.14	42.65	8.06	91 to 112	0.69
Austin, Tex.	475	1916 to 1929	68	148	7.5	2.0	68	28.72	42.47	8.49	77 to 116	0.83
Amarillo, Tex.	3,680	1907 to 1919	56	49	13.0	9.6	56	49.00	66.00	12.63	84 to 109	0.94
Denver, Colo.	5,340	1916	49	...	7.8	4.5	64	38.00	52.15	8.20	....	0.90
Salt Lake, Utah	4,250	1928 to 1930	52	203	6.2	3.6	50	40.67	50.94	10.10	95 to 103	0.69
Yuma, Ariz.	127	1917 to 1929	69	54	5.2	1.3	44	36.29	53.45	9.55	91 to 116	0.69
Independence, Calif.	3,800	1909 to 1911	56	28	6.6	...	45	38.64	55.26	8.00	....	0.83
Salton Sea, Calif.	230	1910	73	...	....	4.1	40	66.35	97.10	13.10	....	0.59
Corvallis, Ore.	235	1922 to 1930	52	...	....	1.5	..	21.88	30.68	5.92	91 to 106	0.69

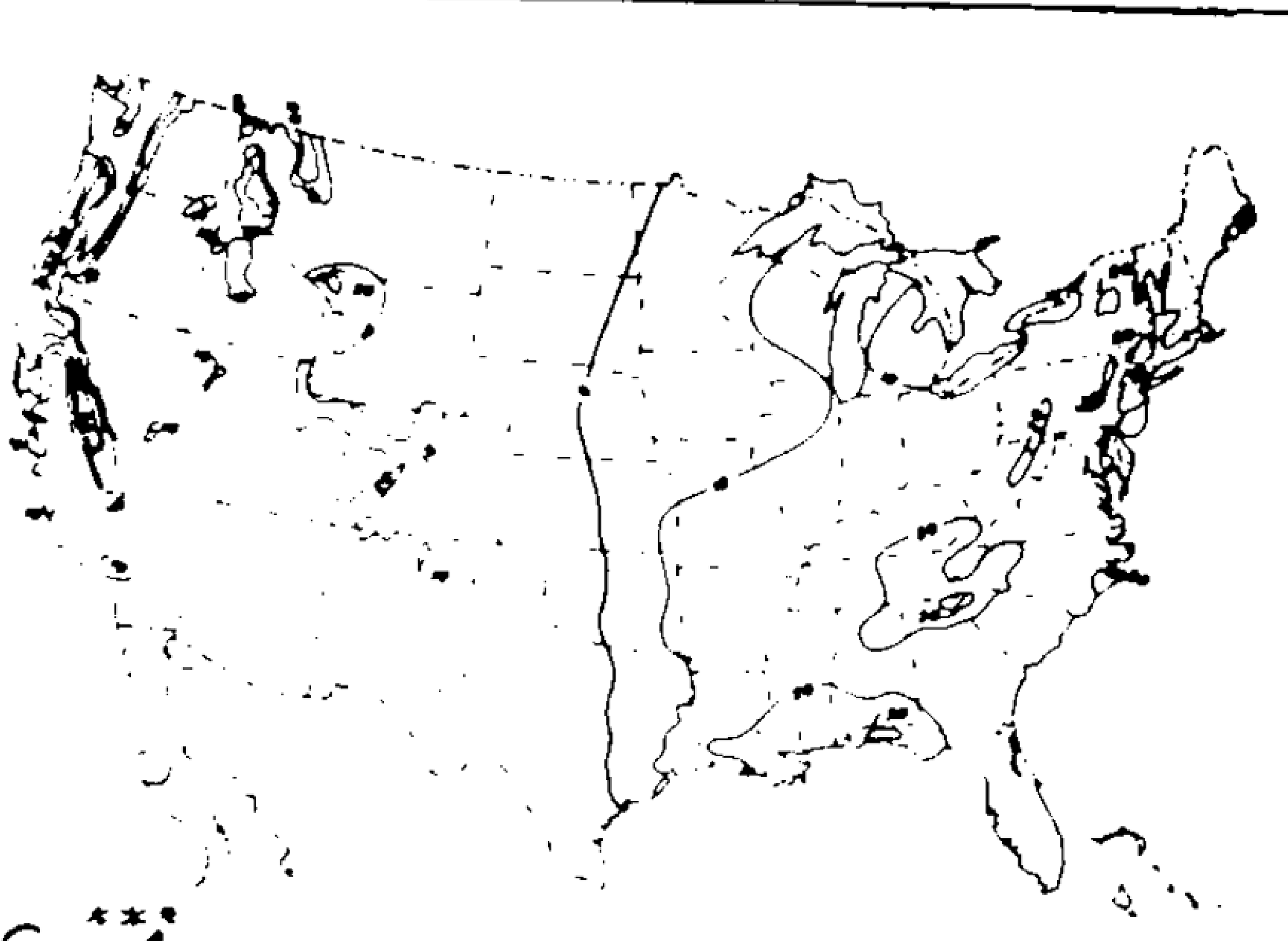


FIG. C - *** Average annual excess of precipitation over the demands of evaporation and transpiration, in inches. West of the zero line there is generally no annual excess except in mountain areas and in the Pacific North West.

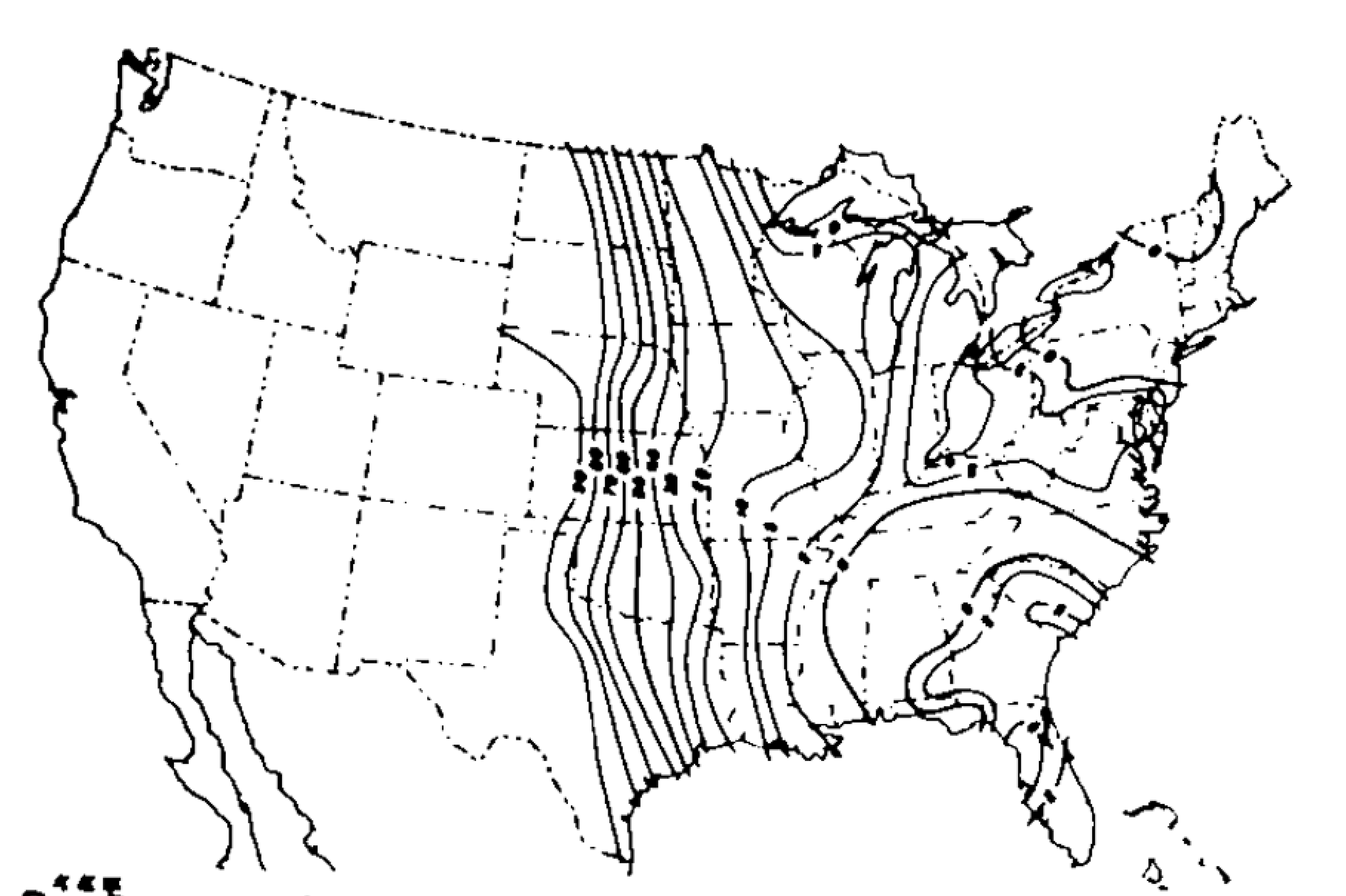


FIG. D - *** Percentage of years that annual precipitation has been less than demands for evaporation and transpiration. Throughout the West, except in mountain areas and the Pacific North West, annual demands of evaporation and transpiration always or nearly always exceed annual precipitation.

* From Public Water Supplies by F.E. Turneaure & H.L. Russell.
** Data from Report - Robert Follansbee - See Trans - A.S.C.E. Vol. 99 Pg. 703.
*** From Physics of the Earth - IX. Hydrology - Published by Mc Graw-Hill.

WATER SUPPLY- DEEP WELLS

General Notes: 1. Well site should be 200 to 500 feet from possible source of pollution. Locate at elevated point if possible to prevent flooding. Fence in well site.

2. Well building should be fireproof, ventilated and in cold climates insulate thoroughly and provide heat. Elevate above grade to provide drainage away from building.

3. Pumping level is determined by continuous flow test at required well capacity, and the measurement of the resulting drawdown below the static water table.

4. The top of screen should be 50 feet min. below grade to avoid surface pollution unless unusually impervious earth (10 feet of compact clay) occurs at the surface, or well is far removed from possible sources of pollution.

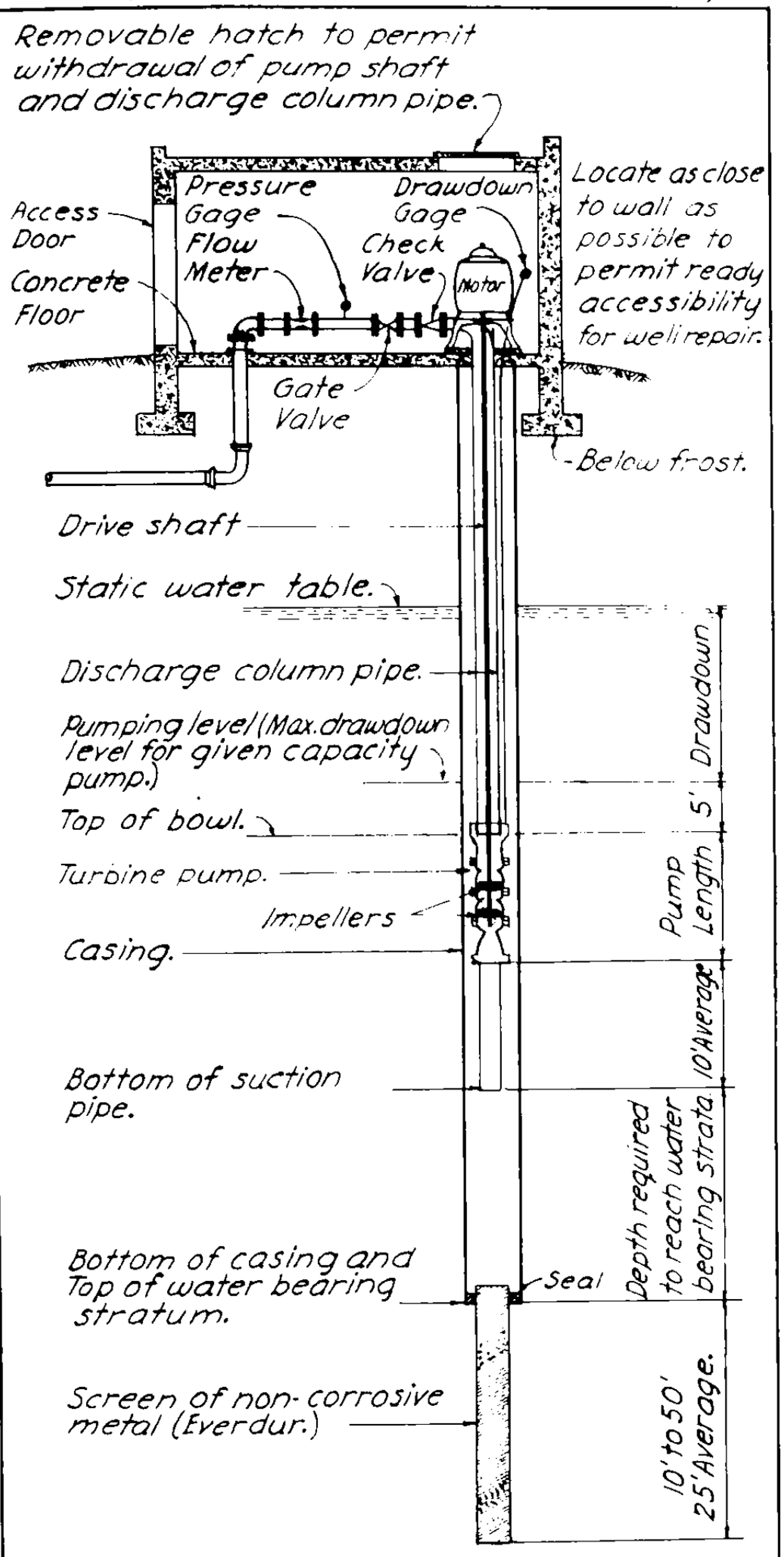


FIG. A- SINGLE CASED WELL.

For use in ordinary sandy and gravelly soil.

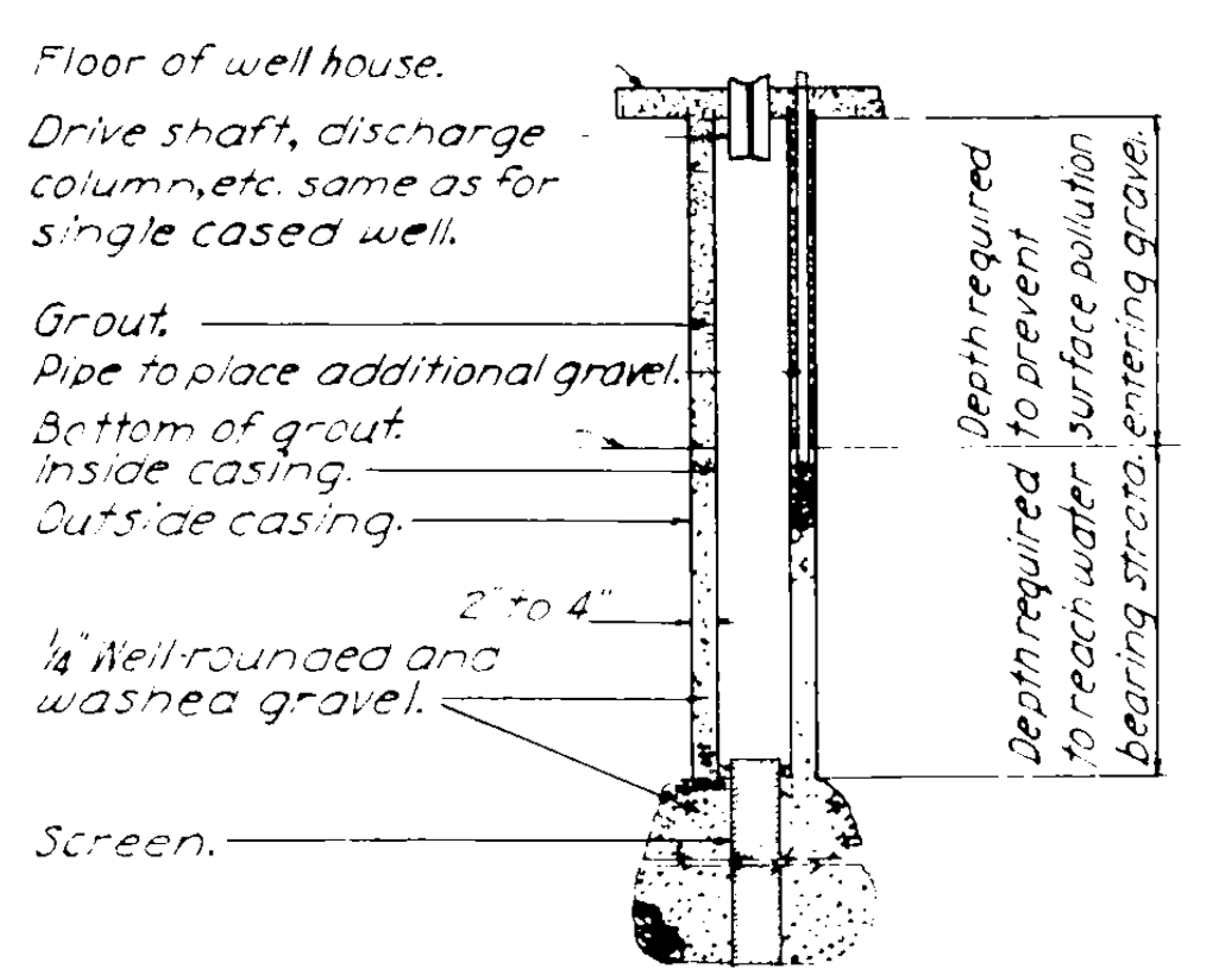
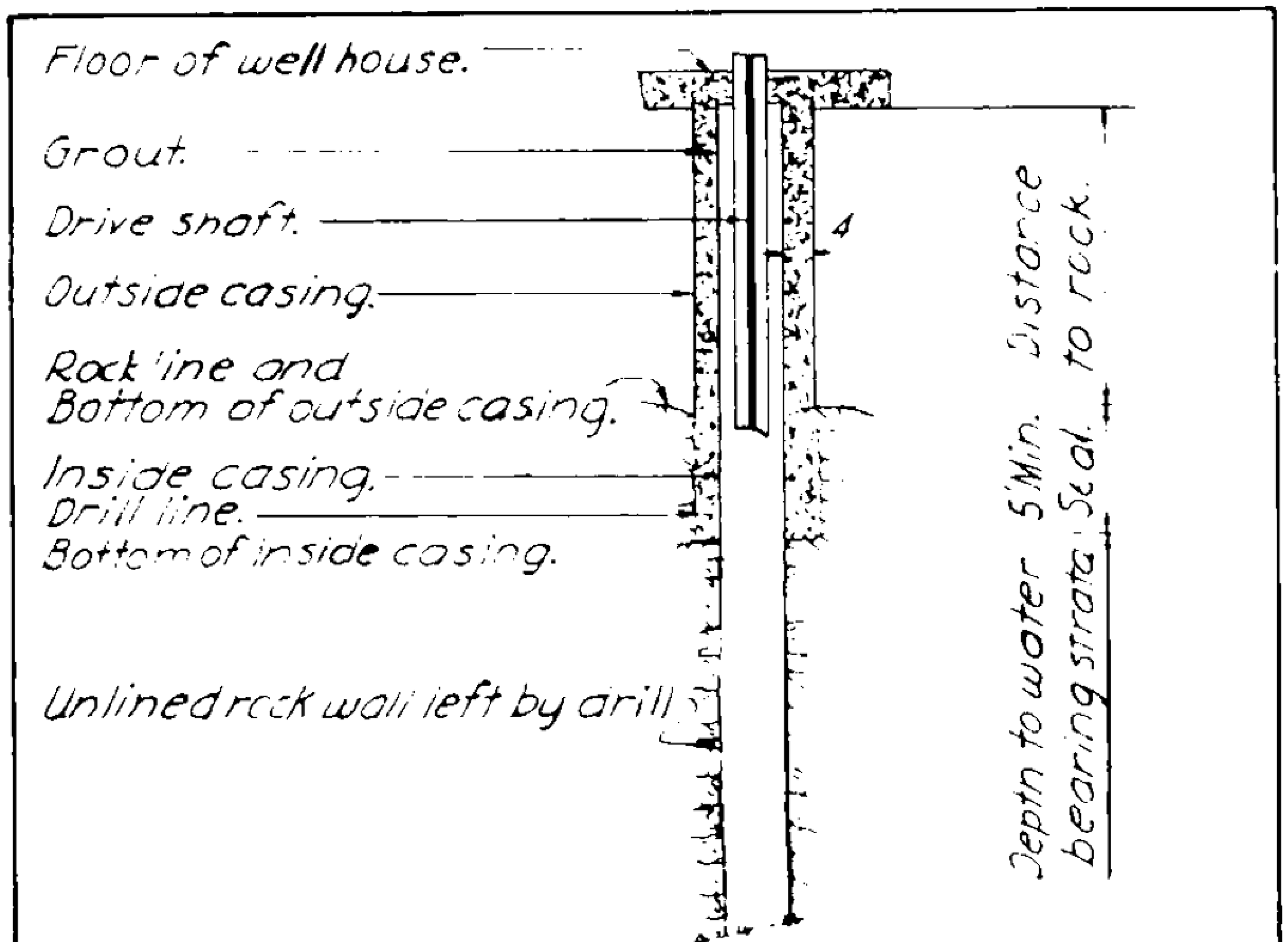


FIG. B-DOUBLE CASED GRAVEL WALL WELL.

For use where water bearing stratum is of uniform fine sand which is subject to flowing at the velocity the water enters the screen. The gravel provides a much larger area than the screen and the velocity of water at the outer line of gravel may be reduced to such velocity that the sand will not flow.



Well house, Pumping level, screen and other details are same as for single cased well.

FIG. C · WELL IN ROCK.

WATER SUPPLY - INTAKES, DOMESTIC WELL, WINDMILLS

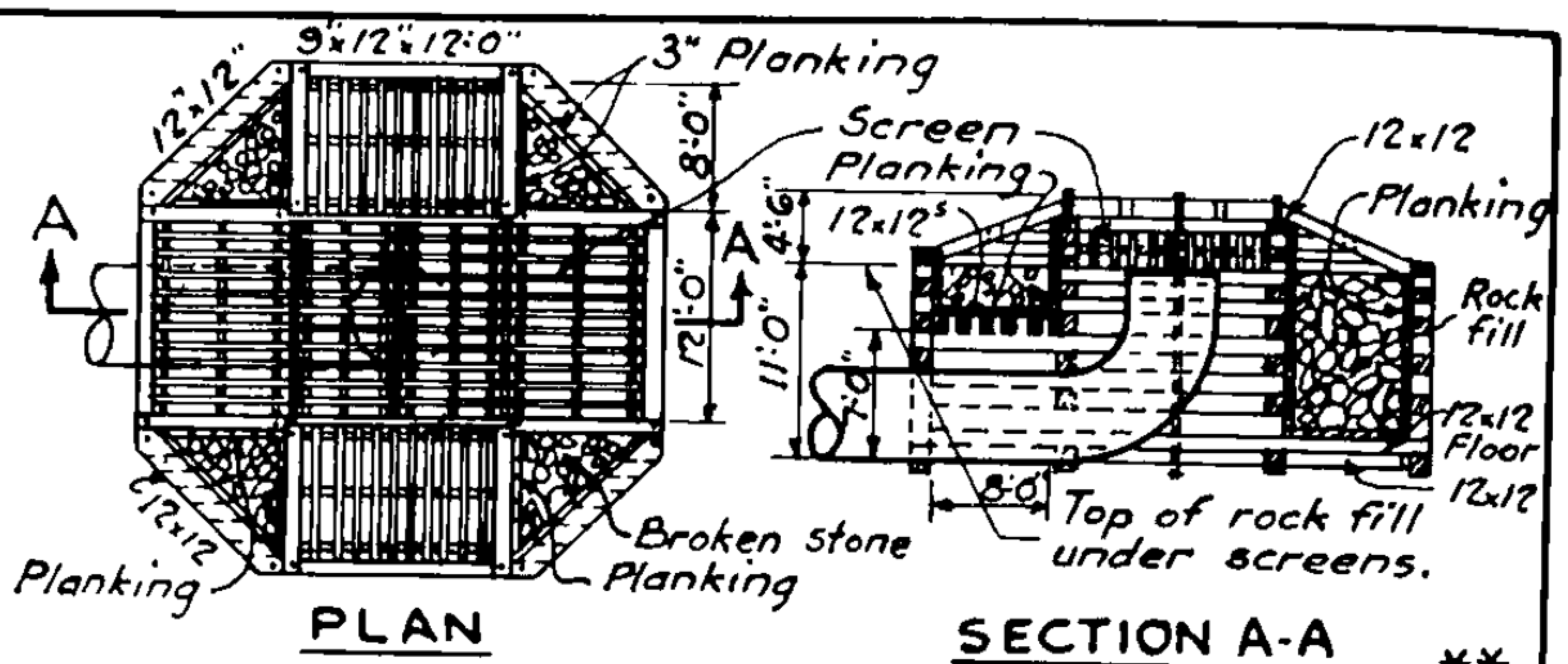


FIG. A - CRIB INTAKE FOR LAKE OR DEEP RIVER**

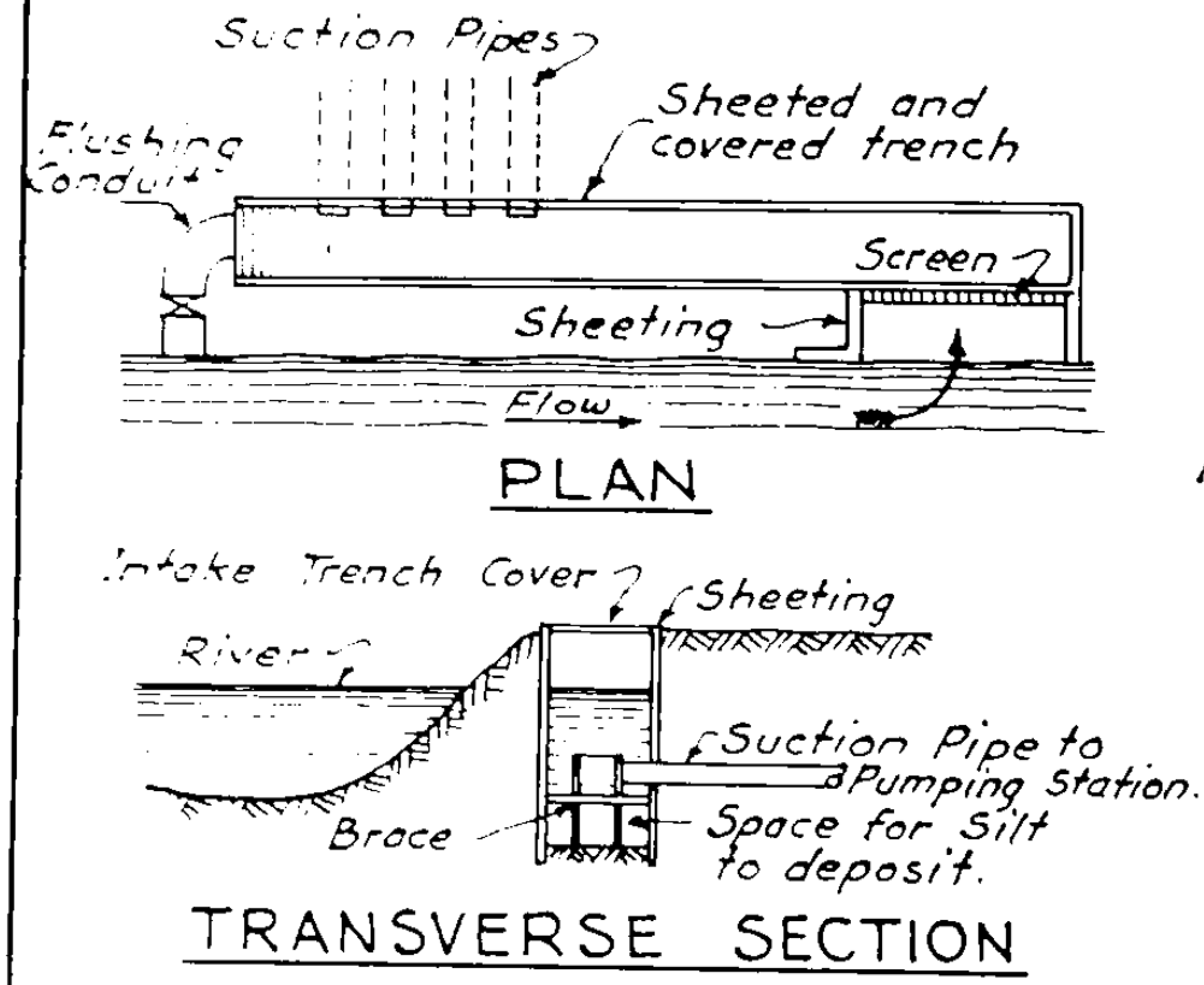


FIG. B - INTAKE AT SIDE OF RIVER*

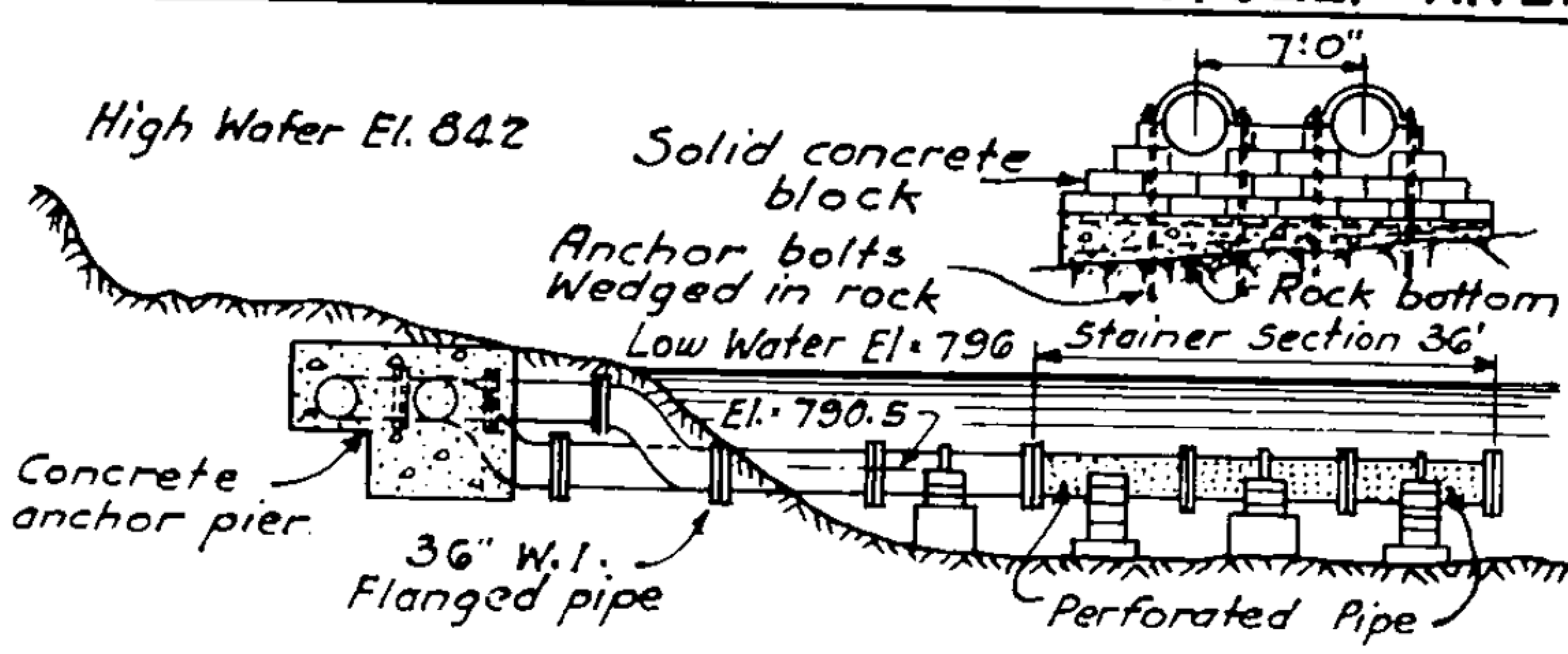


FIG. C - PERFORATED PIPE INTAKE AT KNOXVILLE-TENN.***

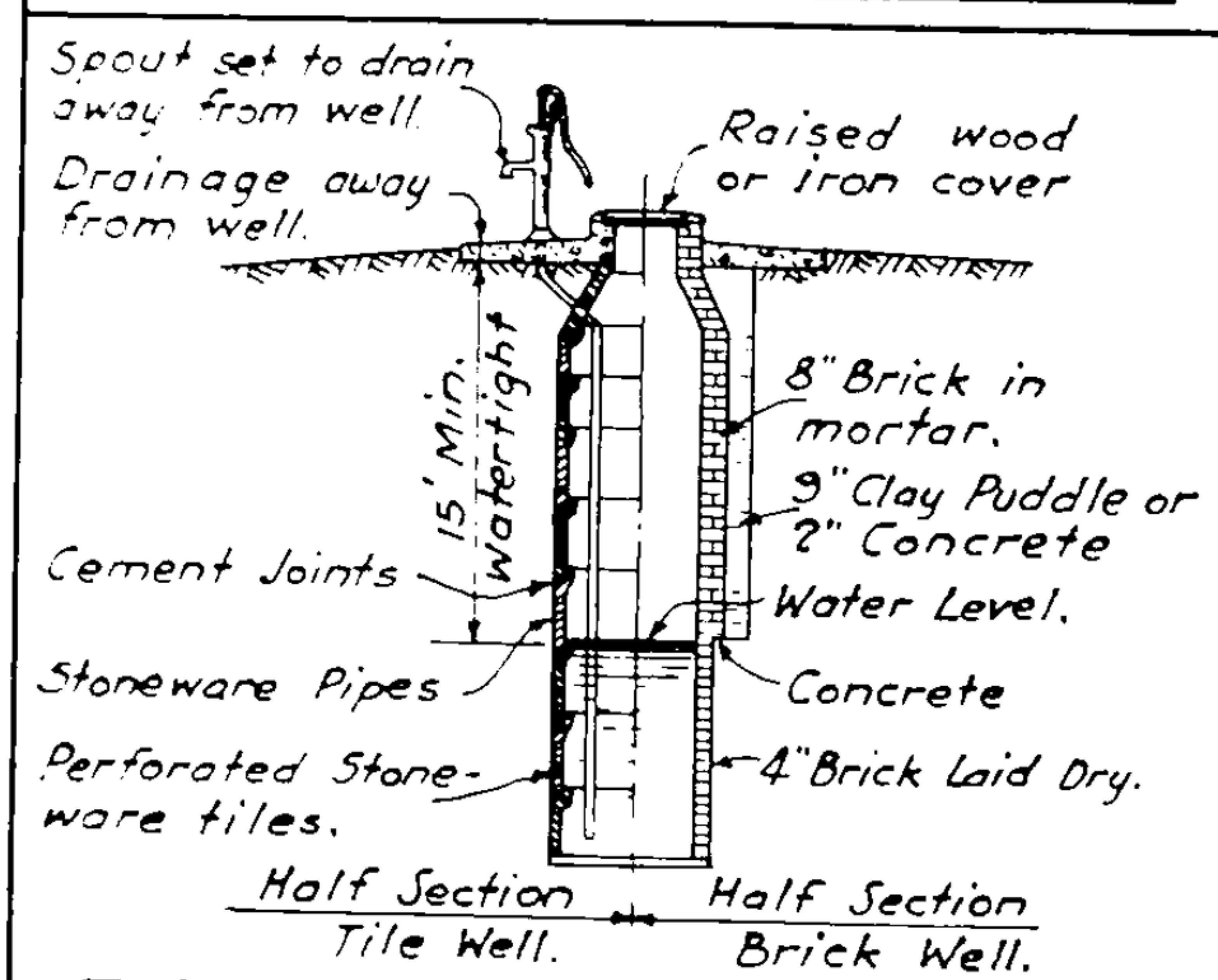


FIG. E - DOMESTIC WELL.*

NOTE FOR ALL INTAKES

All Screens and racks to have sufficient clear openings to give velocity through screen or rack of less than 30' per minute.

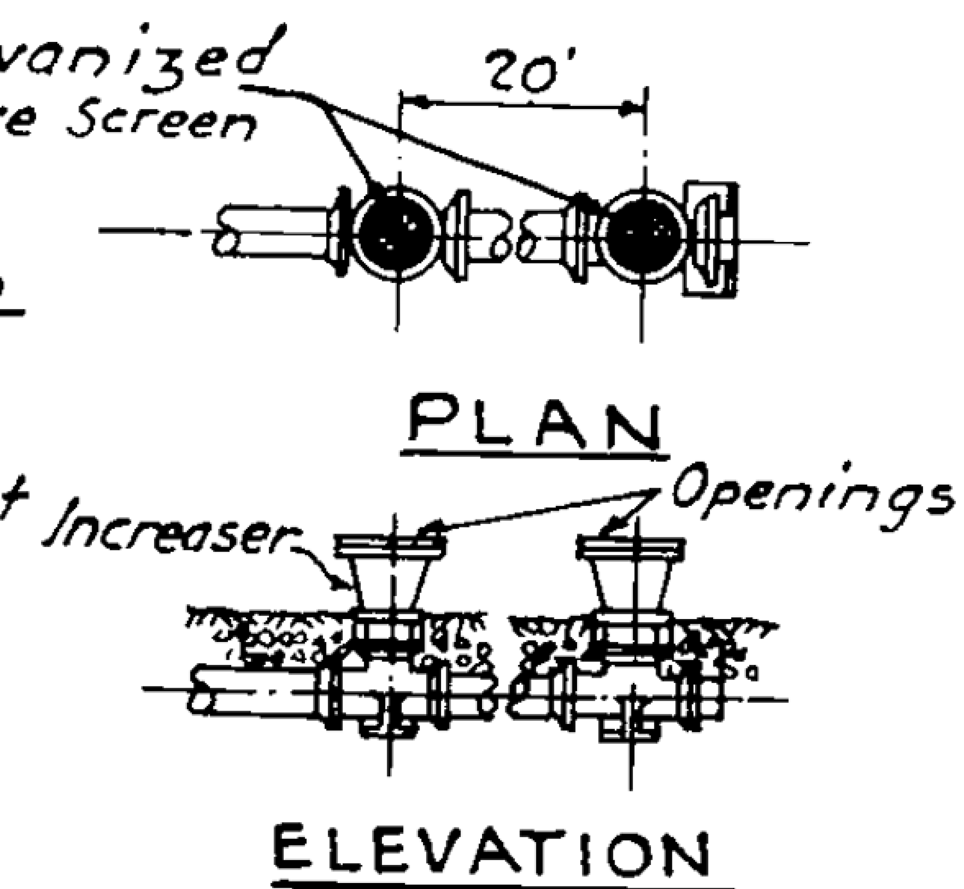


FIG. D - INTAKE OF UPTURNED TEES

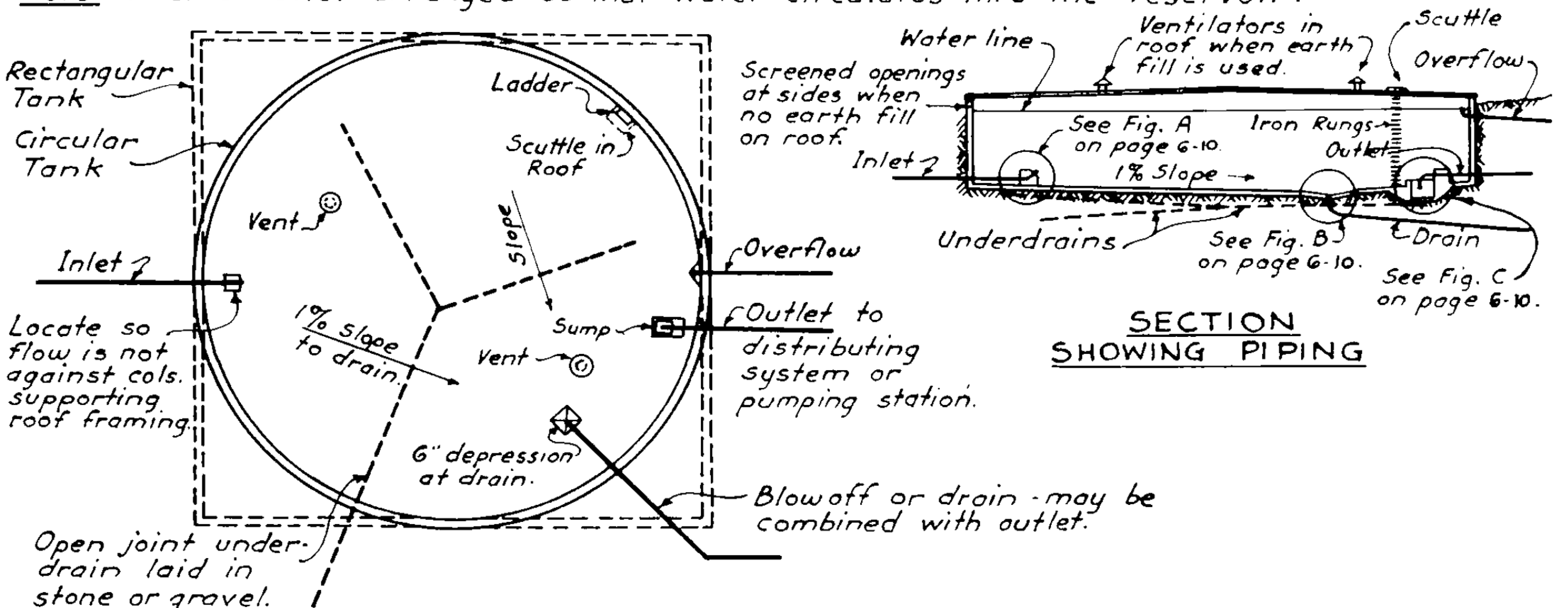
TABLE F - CAPACITIES OF WINDMILLS - GALS. PER MIN. *

Diameter of blades in feet	Velocity of wind in miles per hour	Revolutions of wheel per minute	ELEVATION - FEET - RAISED 25 ft.	50 ft.	75 ft.	100 ft.	150 ft.	200 ft.	Equivalent actual useful h.p. developed
8½	16	70 to 75	6.19	3.02	------	------	------	-----	0.04
10	16	60 to 65	19.2	9.56	6.64	4.75	-----	-----	0.12
12	16	55 to 60	33.9	17.9	11.8	8.44	5.68	-----	0.21
14	16	50 to 55	45.1	22.6	15.3	11.2	7.81	5.00	0.28
16	16	45 to 50	64.6	31.6	19.5	16.2	9.77	8.08	0.41
18	16	40 to 45	97.7	52.2	32.5	24.4	17.5	12.2	0.61
20	16	35 to 40	125.0	63.7	40.8	31.2	19.3	15.9	0.78
25	16	30 to 35	212.0	107.0	71.6	49.7	37.3	26.7	1.34

*Adapted from Waterworks Handbook by Flinn, Weston & Bogert, McGraw-Hill
**Adapted from Babbitt & Doland, Water Supply Engineering, McGraw-Hill.
***Adapted from Engineering News Record.

WATER SUPPLY - DISTRIBUTING RESERVOIRS -1

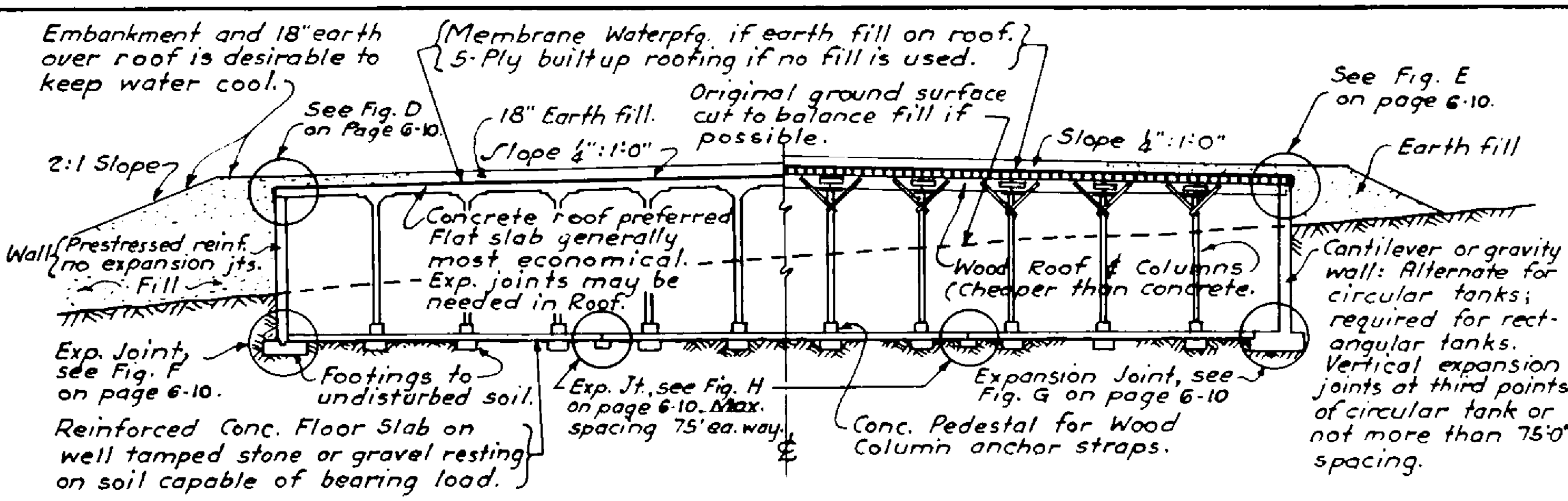
Note:- Inlet & Outlet arranged so that water circulates thru the reservoir.



PLAN

SECTION SHOWING PIPING

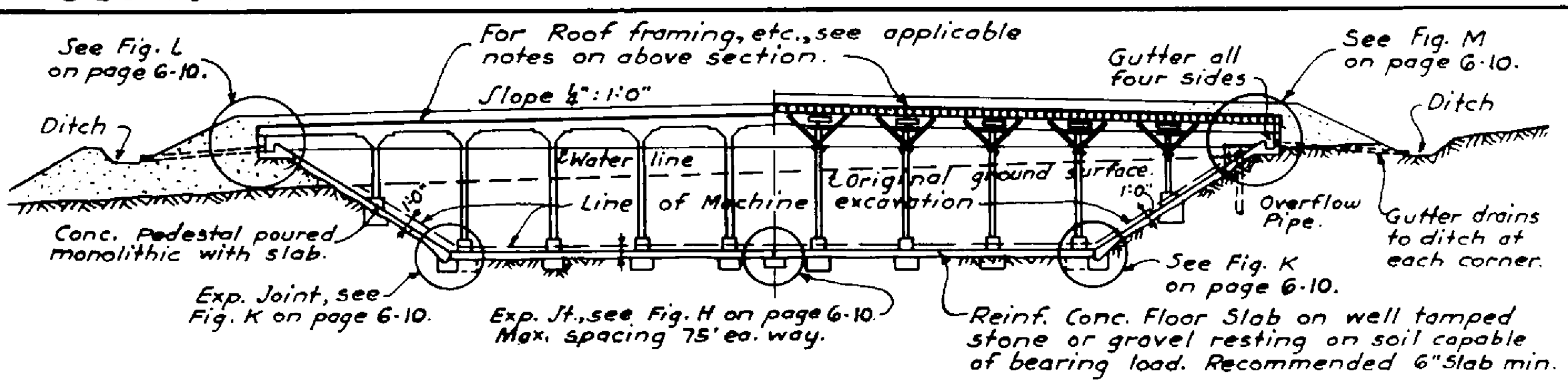
REQUIRED PIPING FOR RESERVOIRS



CIRCULAR TANK

RECTANGULAR TANK

SECTION THRU TANK TYPE RESERVOIR - CIRCULAR OR RECTANGULAR



SECTION THRU PAVED CAVITY TYPE RESERVOIR

Note:- Distributing Reservoirs are also construated with earth and rock fill walls; see pg. 4-70 to 4-73.

WATER SUPPLY - DISTRIBUTING RESERVOIRS-2

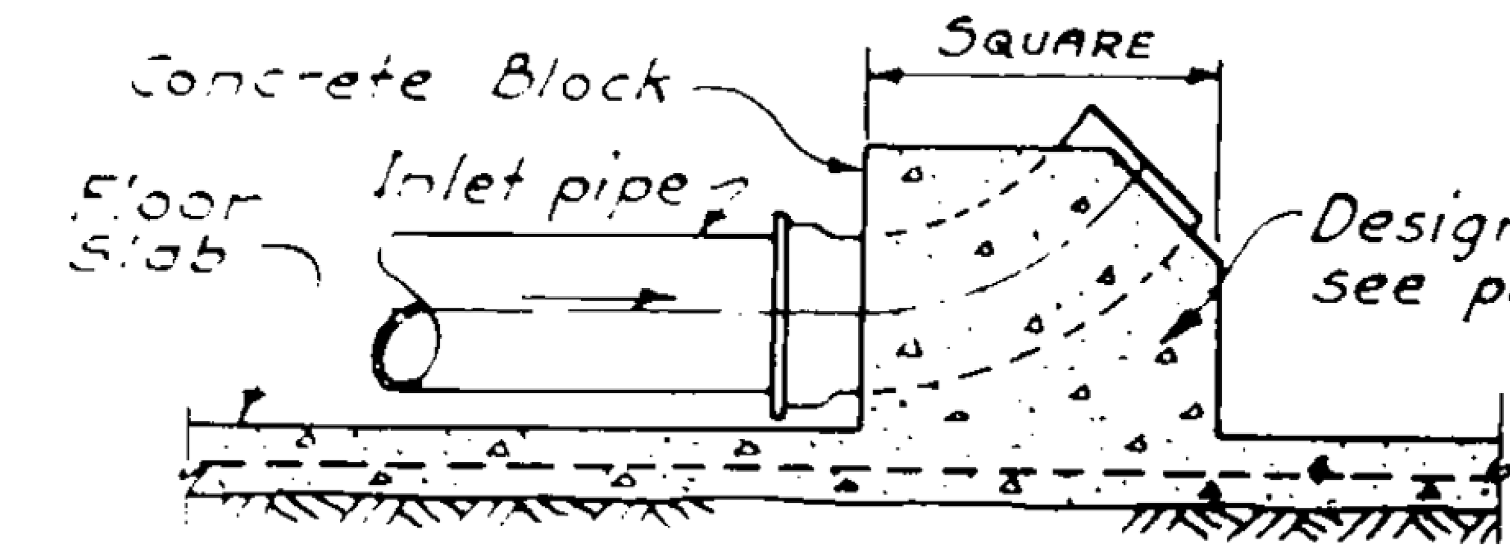
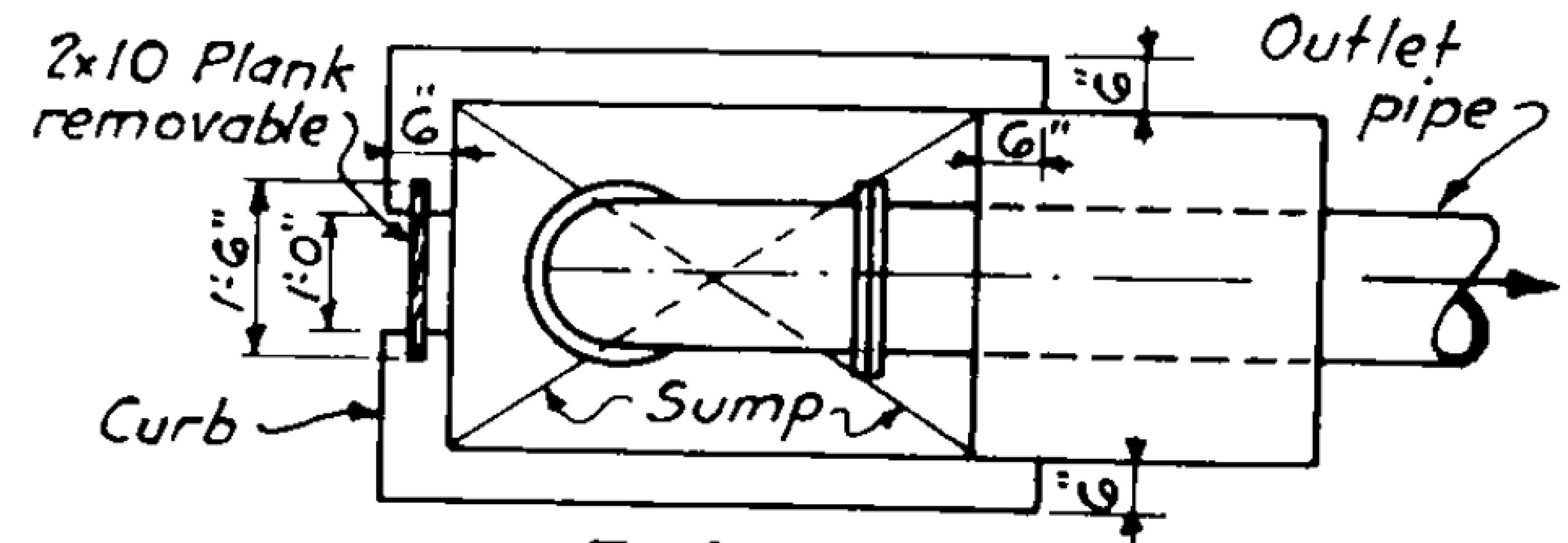


FIG. A



·PLAN·

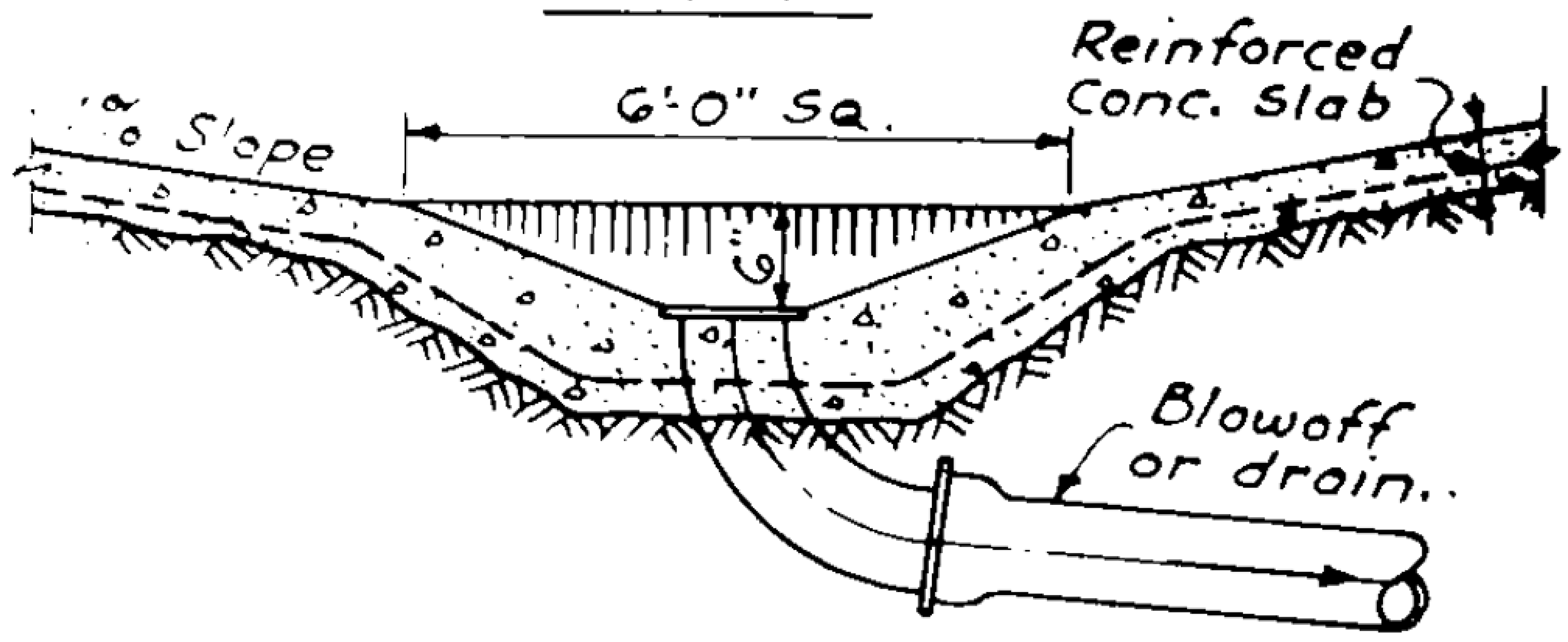


FIG. B

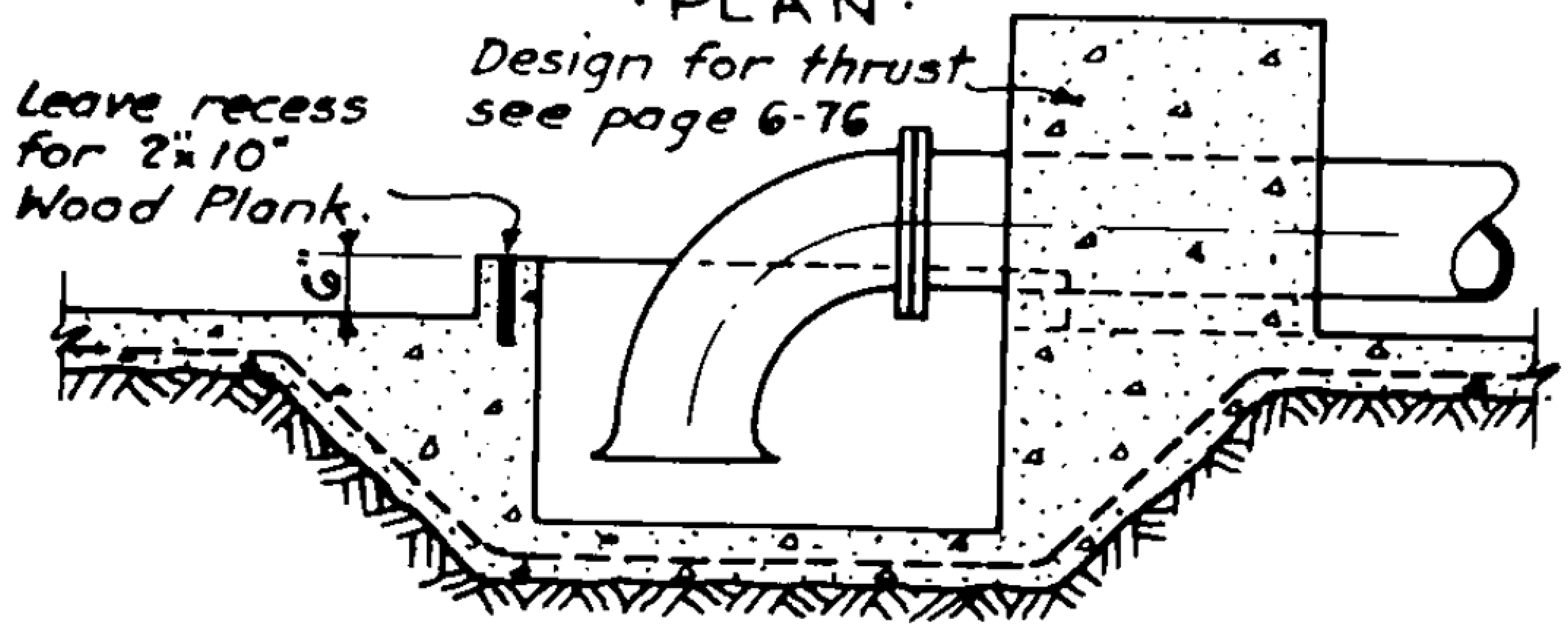


FIG. C

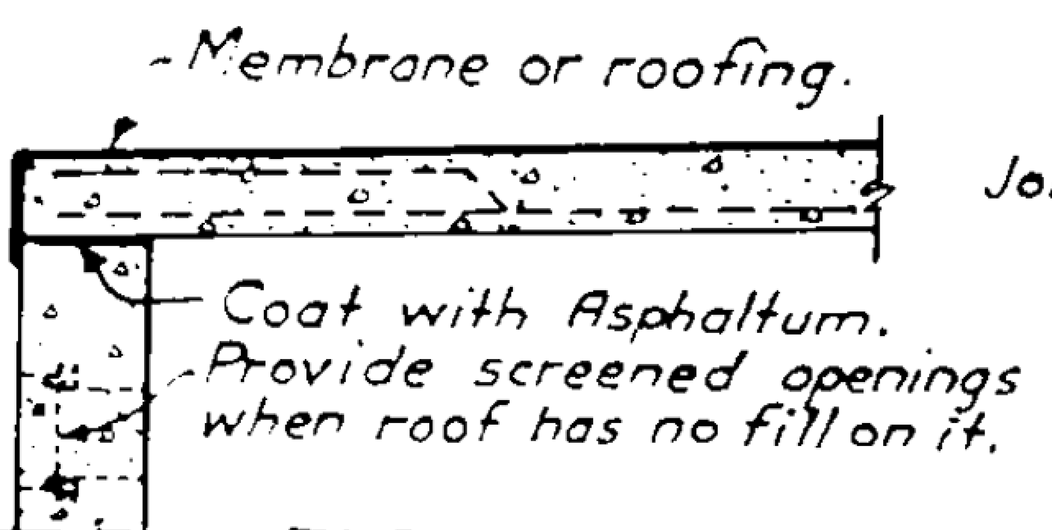


FIG. D

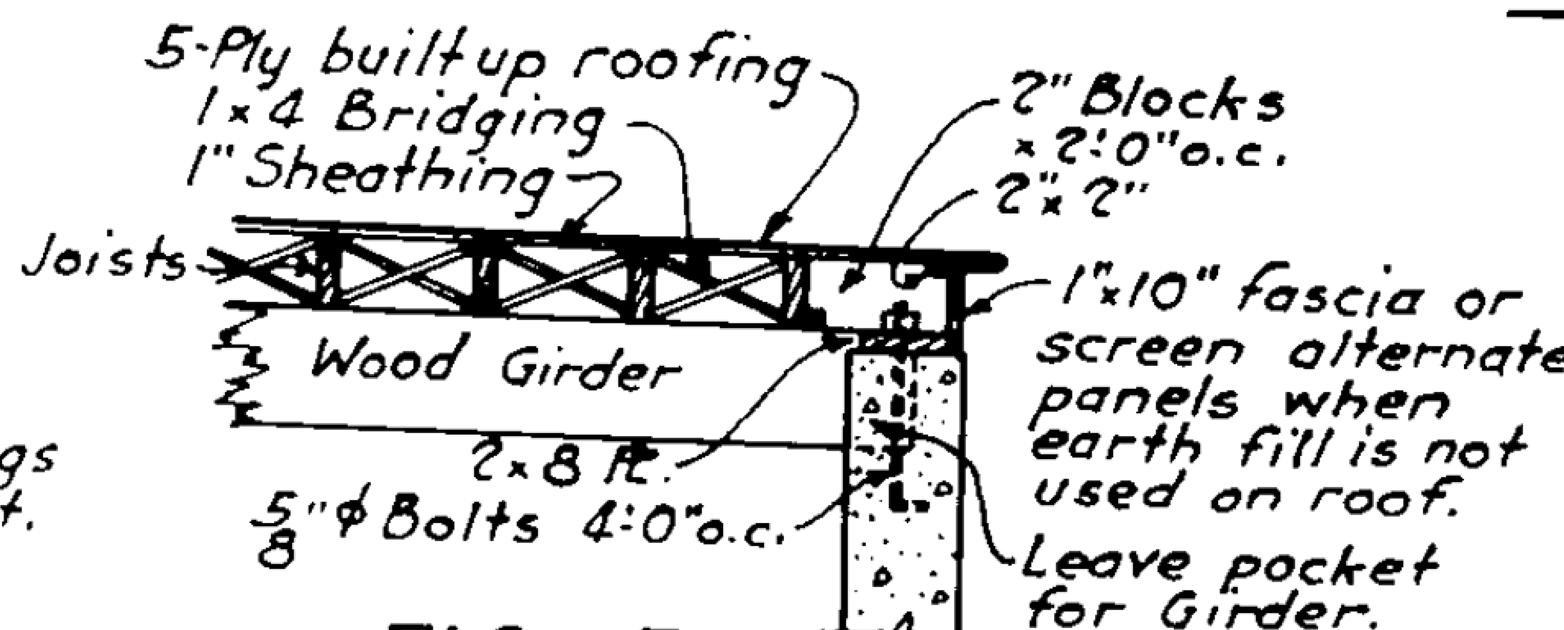


FIG. E

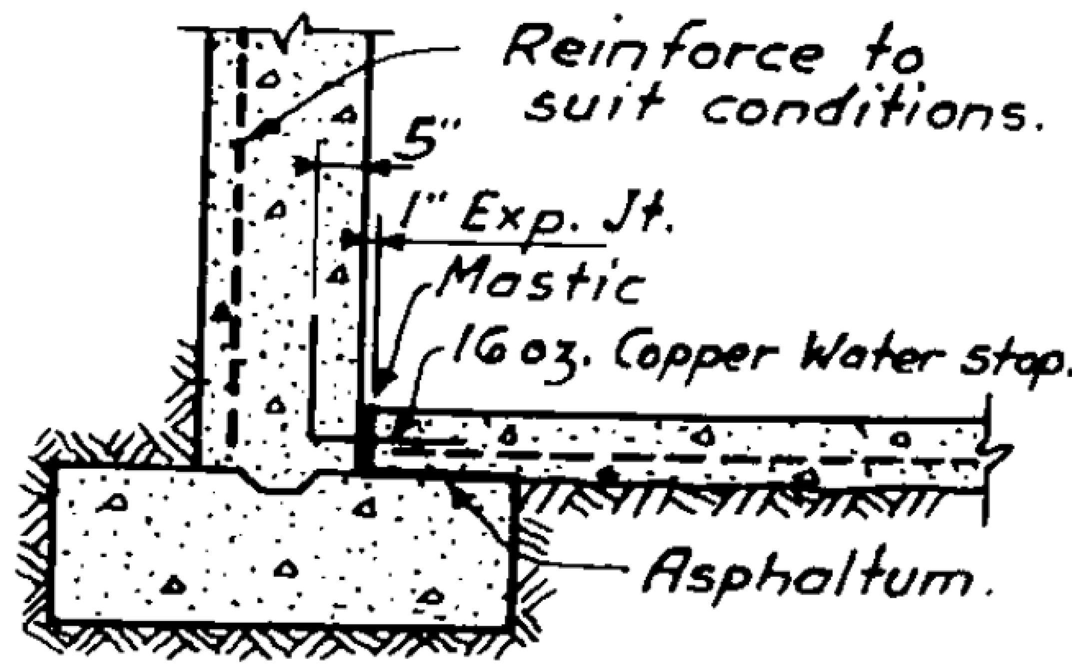


FIG. F

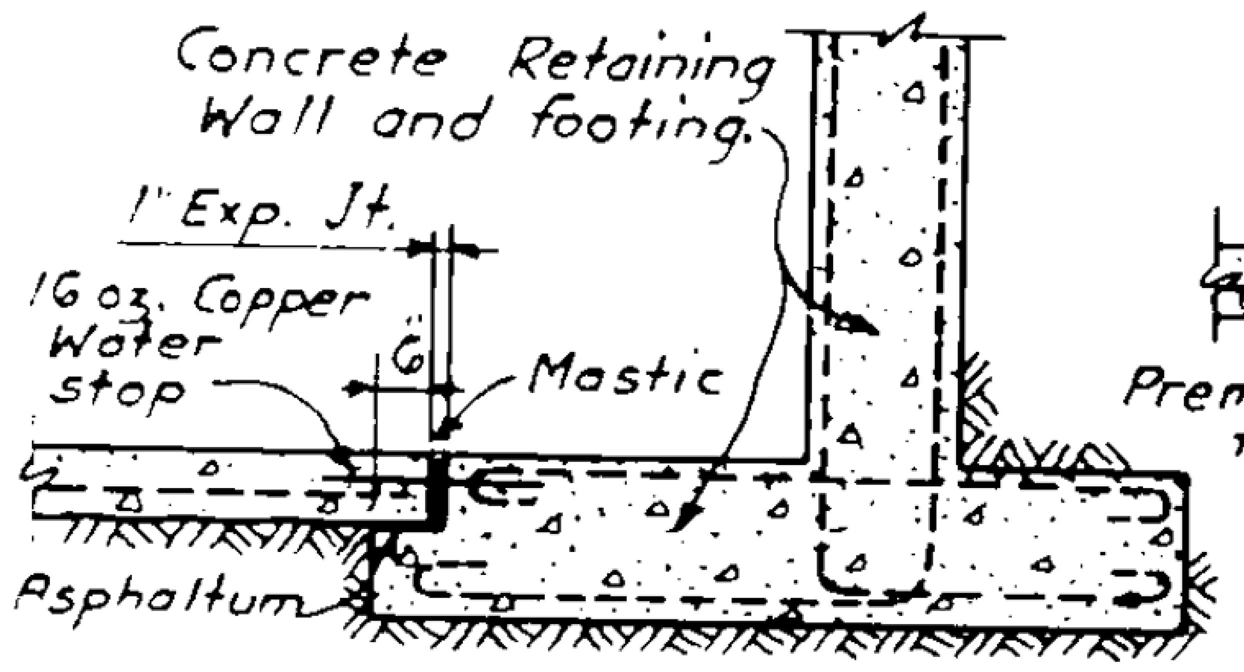


FIG. G

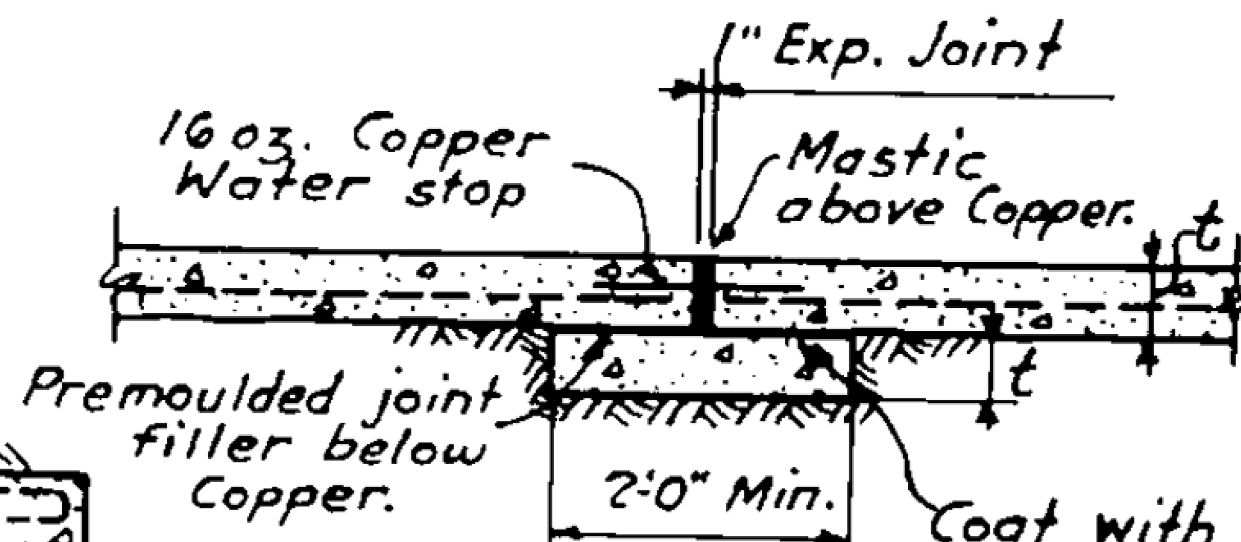
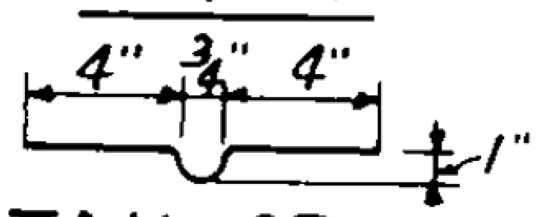


FIG. H



DETAIL OF COPPER WATER STOP

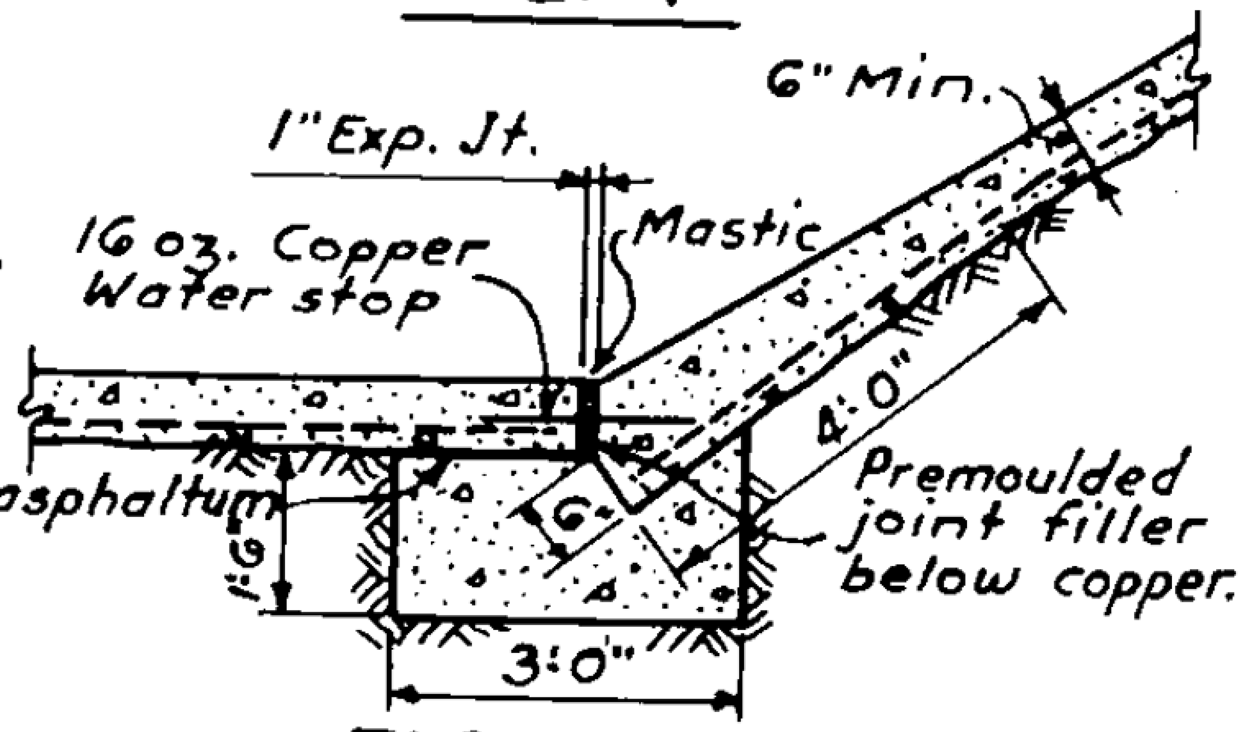


FIG. K

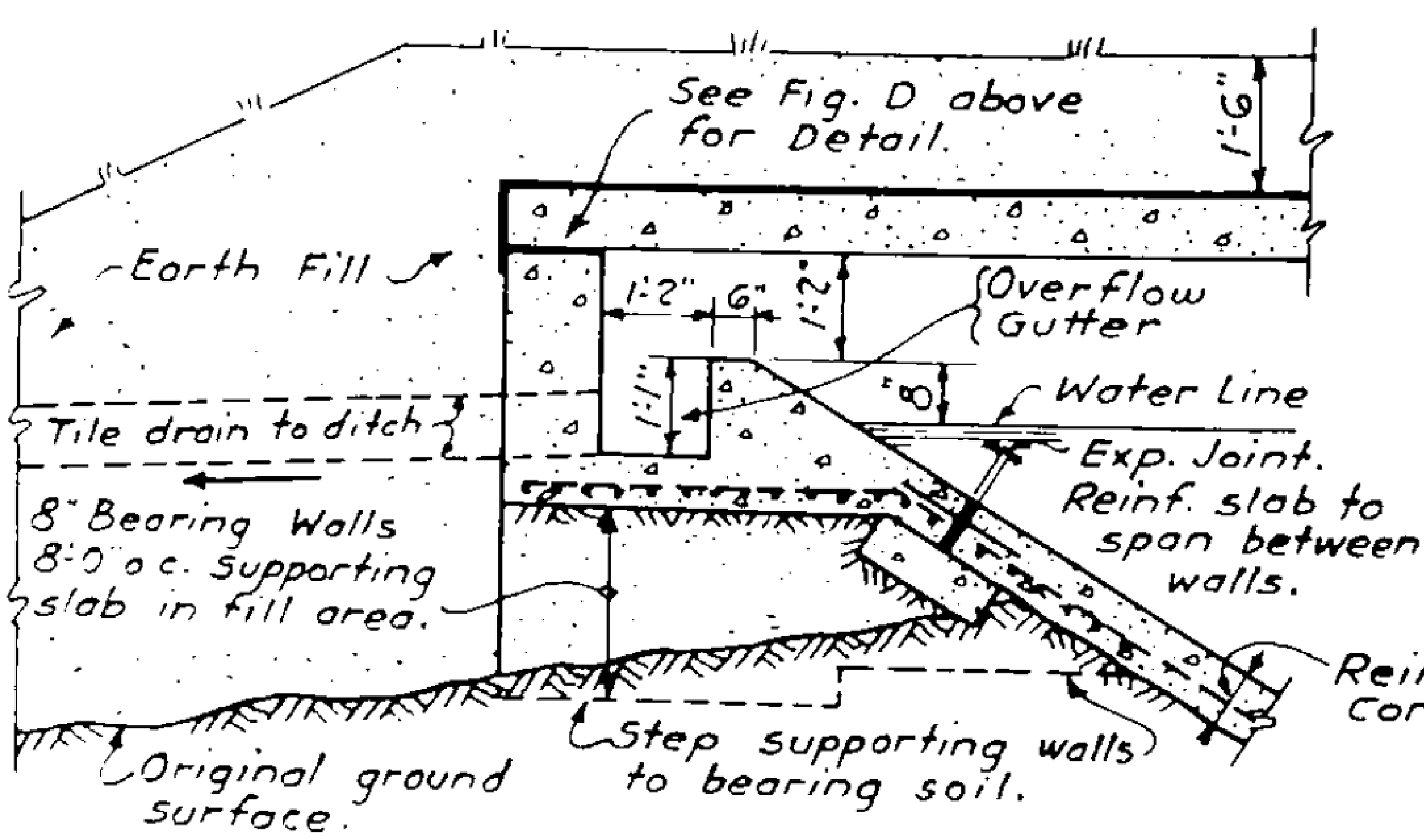


FIG. L

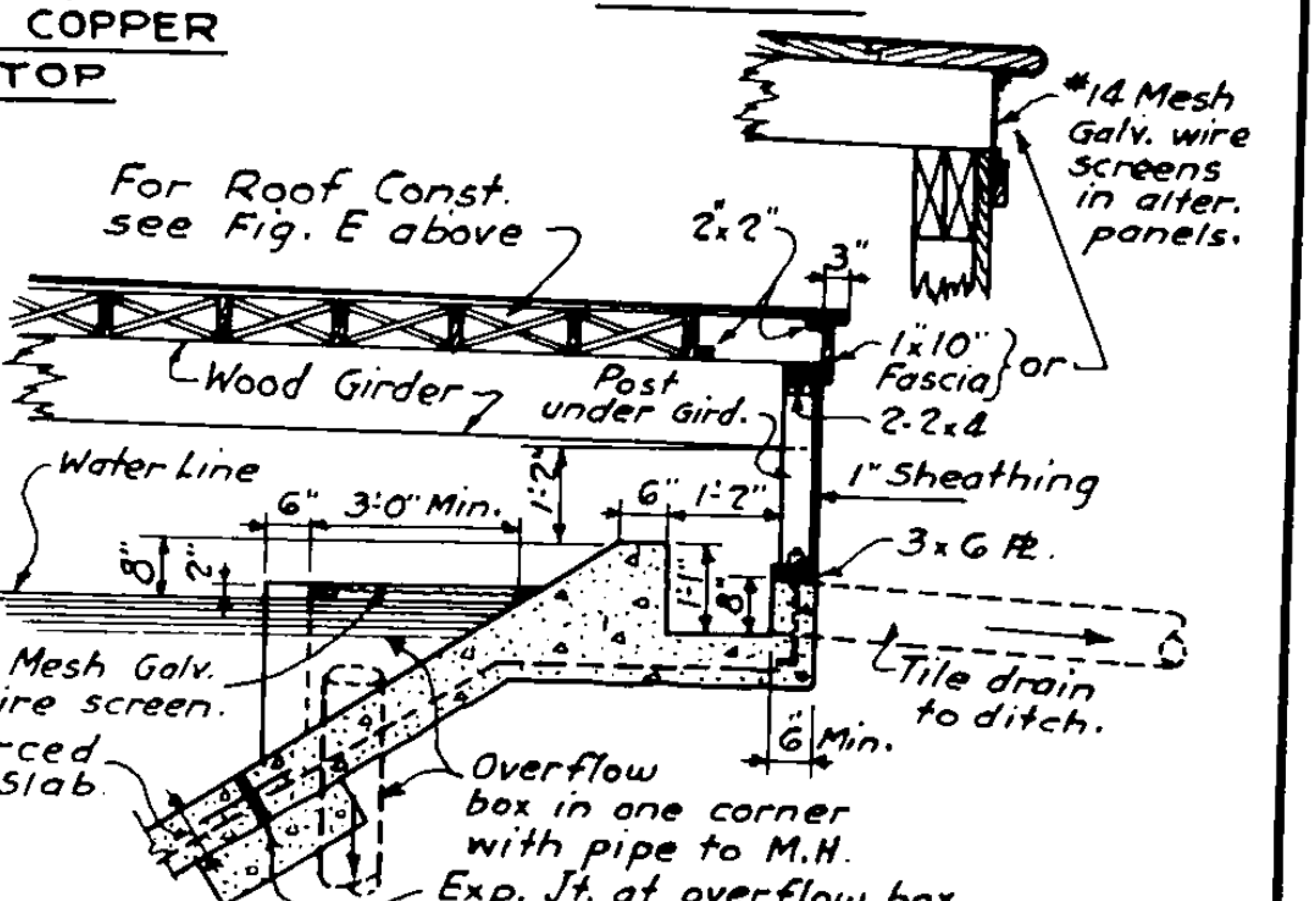
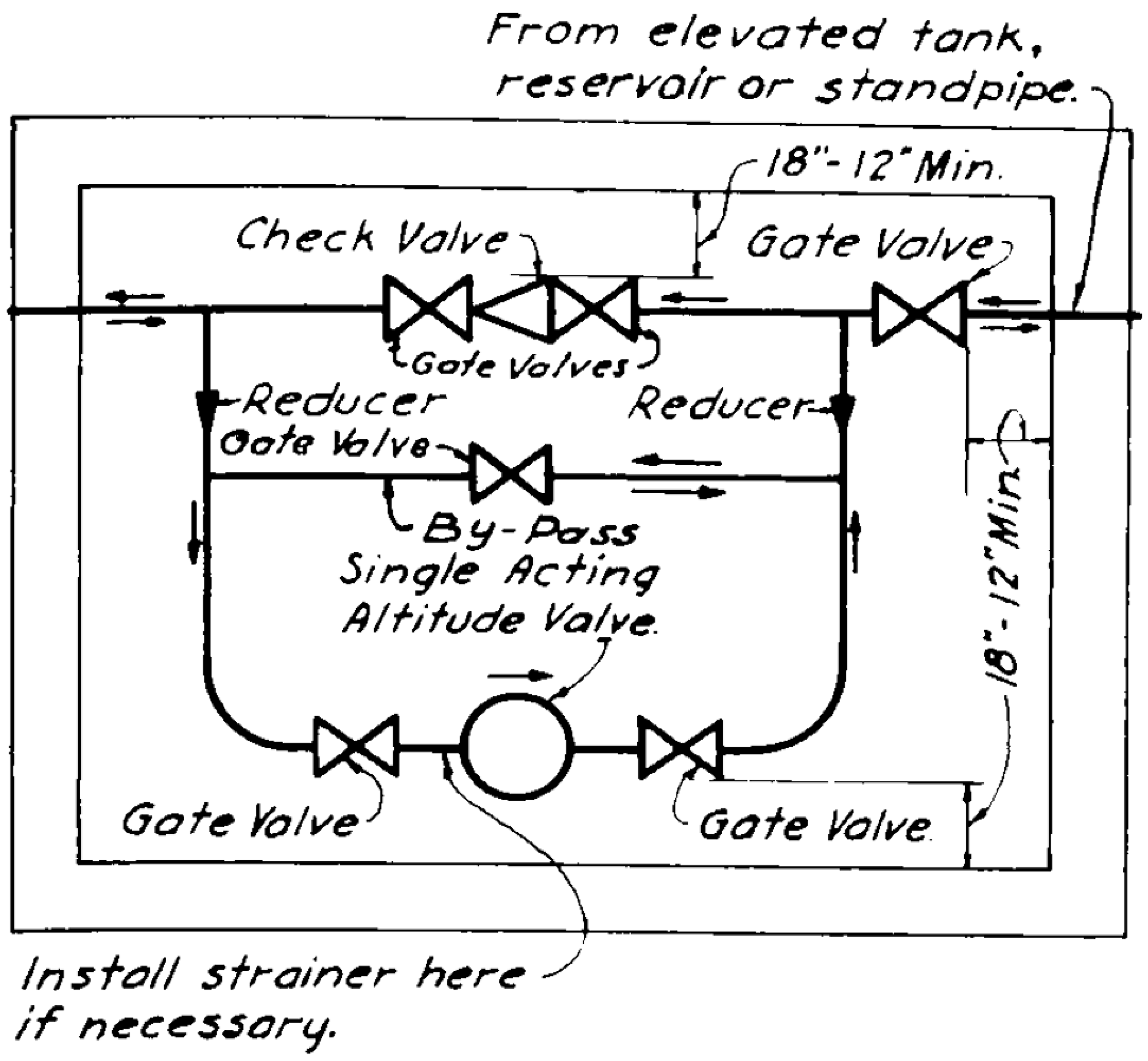


FIG. M

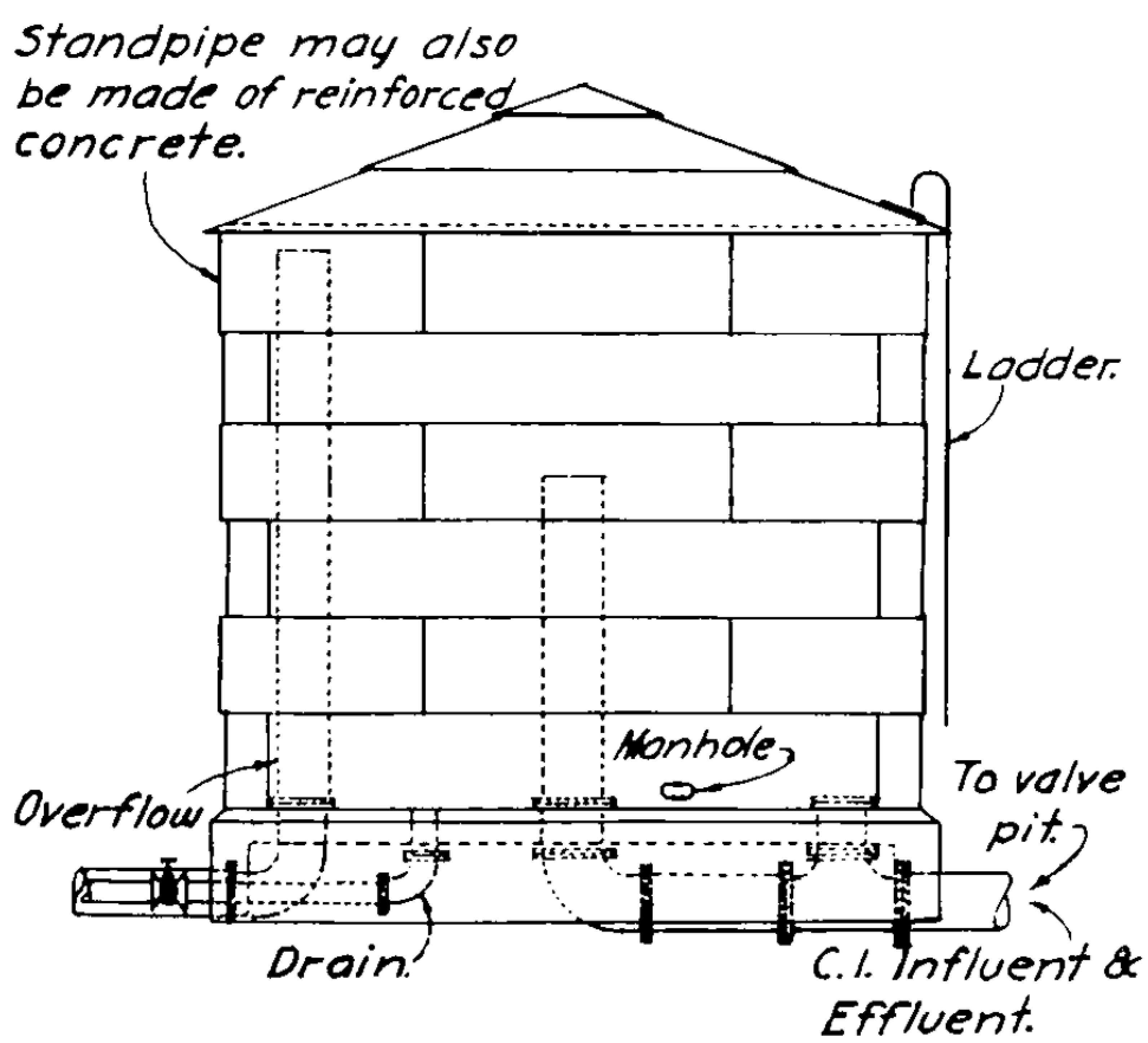
NOTE: For location of above Figures see Pg. 6-09.

WATER SUPPLY- ELEVATED STORAGE TANKS



Provisions should be made for heating in extremely cold weather. If heater is not used, an additional inside manhole cover of 2" plank or its equivalent shall be installed at least 4" below the outer cover.

FIG. A- TYPICAL VALVE PIT DETAILS.



Useful storage capacity is volume above elevation required to give necessary pressure, usually top 25 feet.

FIG. B- TYPICAL STANDPIPE* INSTALLATION

*From Babbitt & Doland, Water Supply Engineering, McGraw-Hill.

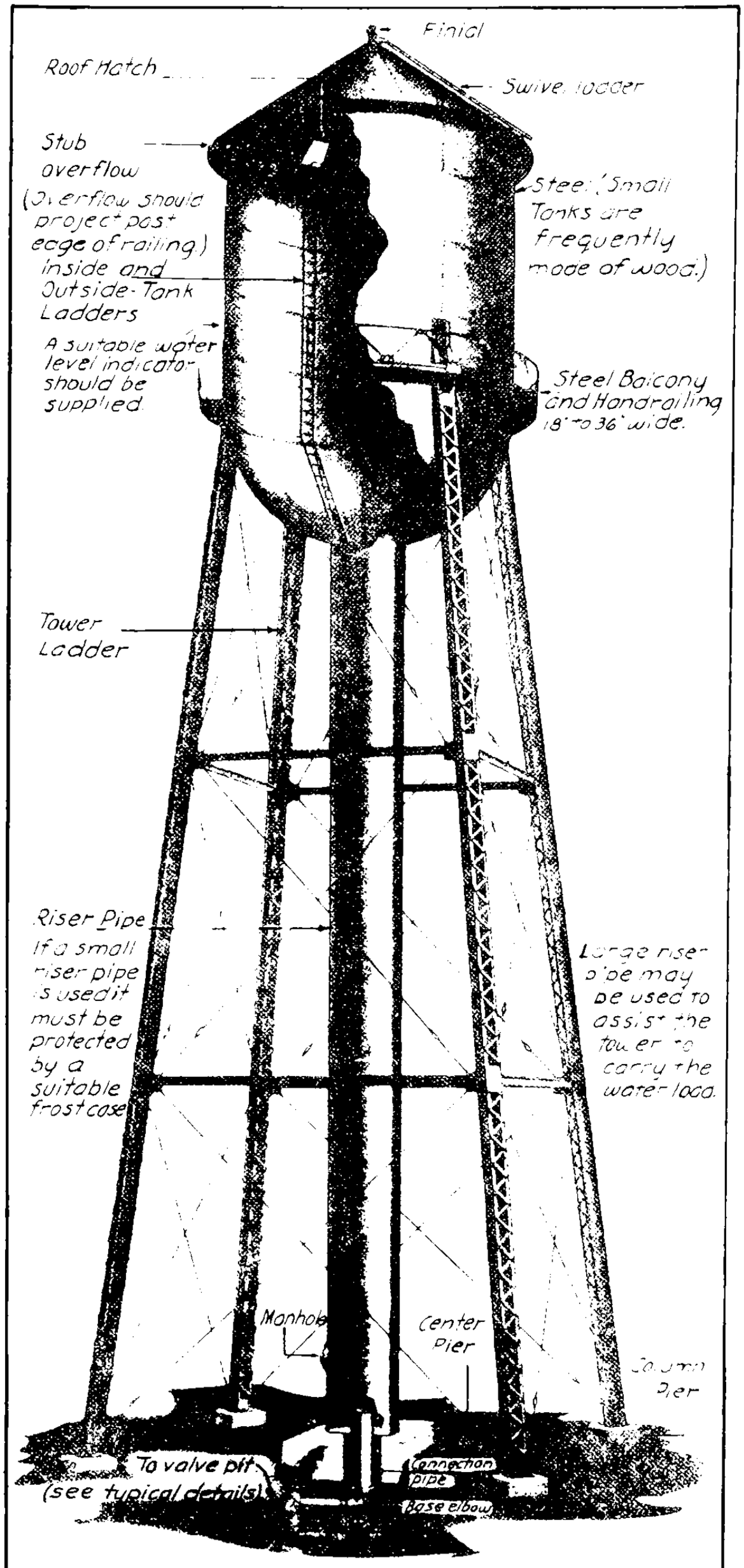


FIG. C - PARTS OF ELEVATED STORAGE TANK.**

**From Pittsburgh-Des Moines Steel Co Bulletin No 101.

WATER SUPPLY - PUMPING

VARIATION IN DEMAND

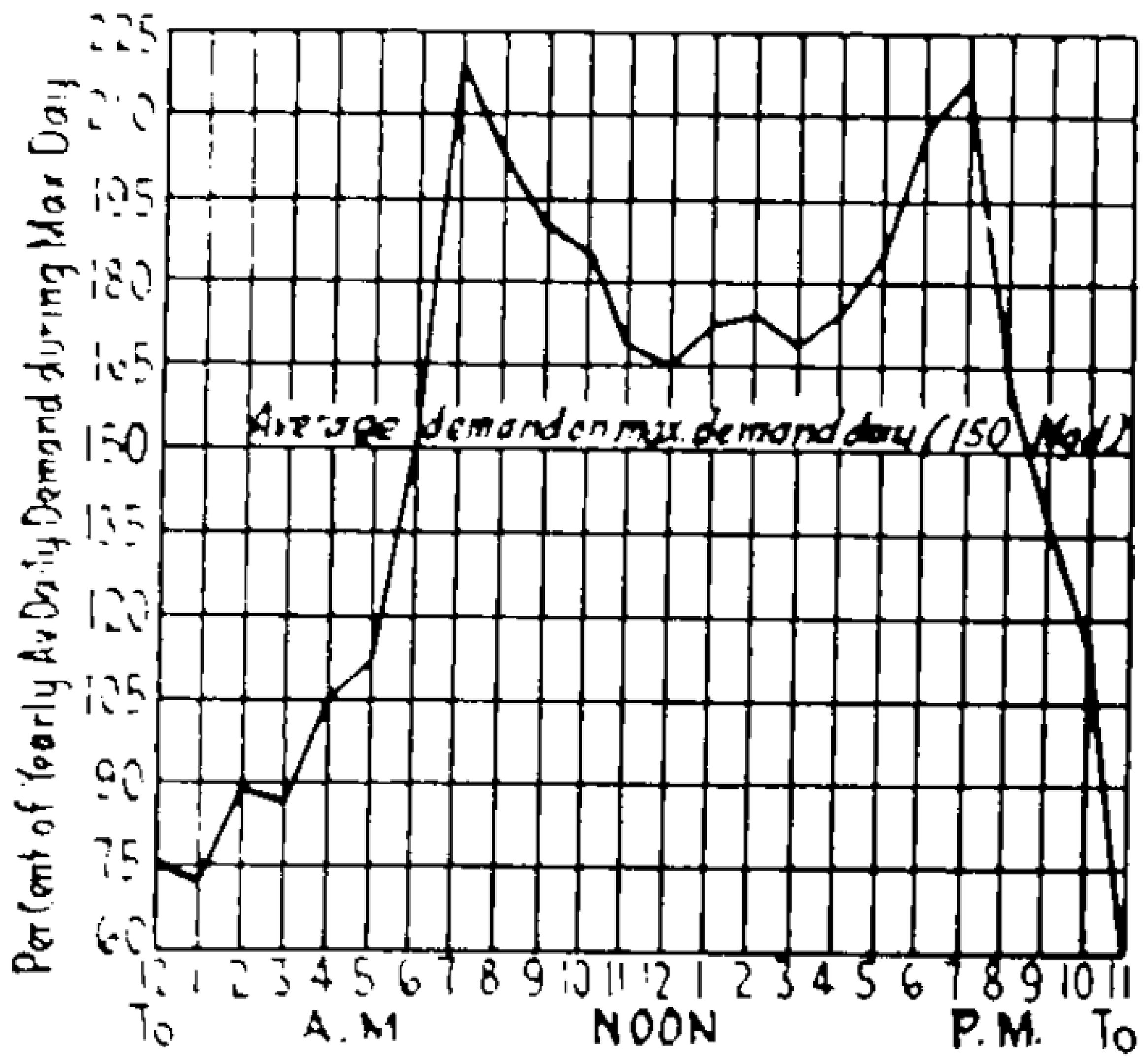


FIG. A-HOURLY IN A MAX. DAY* AT CLEVELAND, OHIO

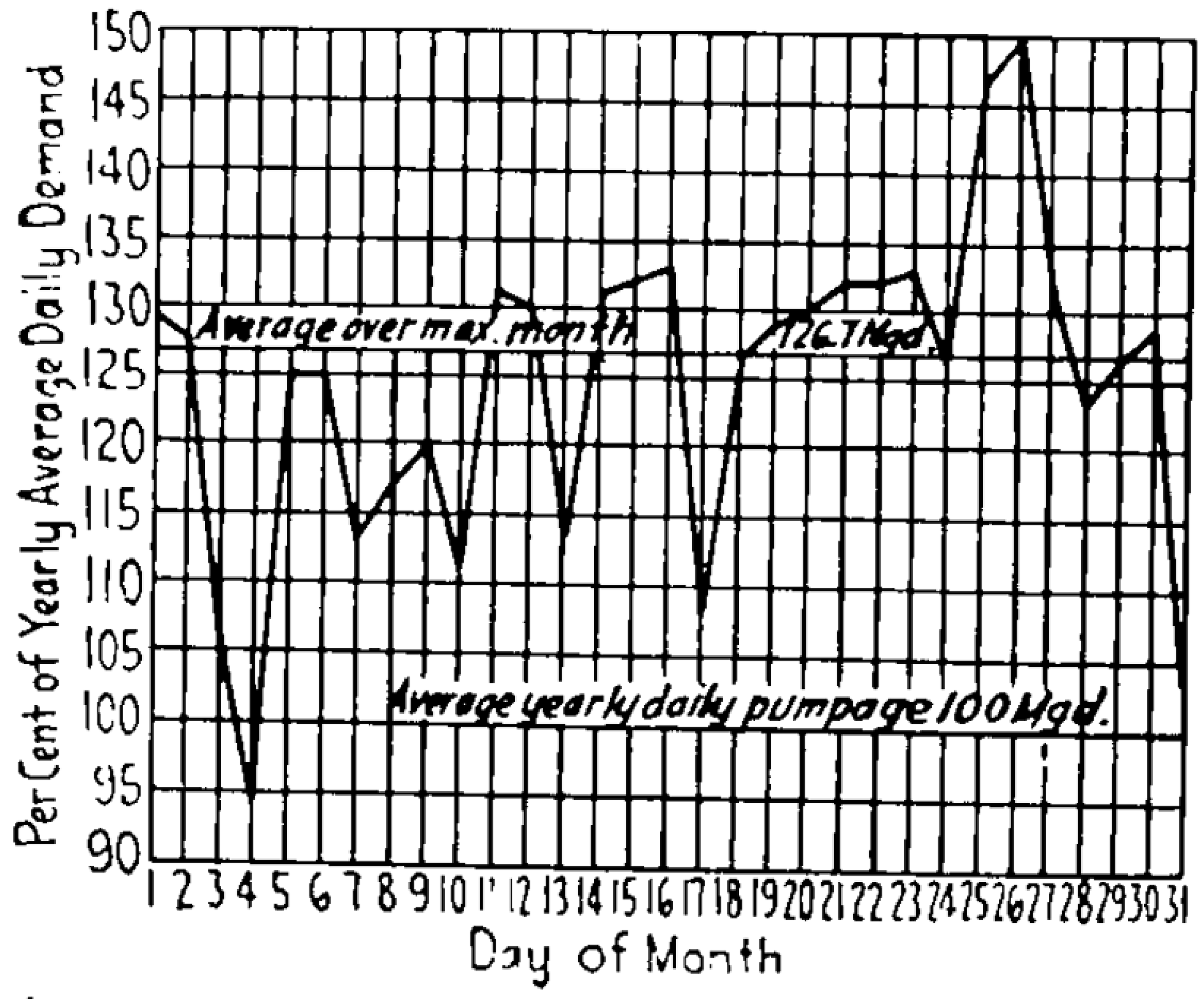


FIG. B-DAILY IN A MAX. MONTH* AT CLEVELAND, OHIO

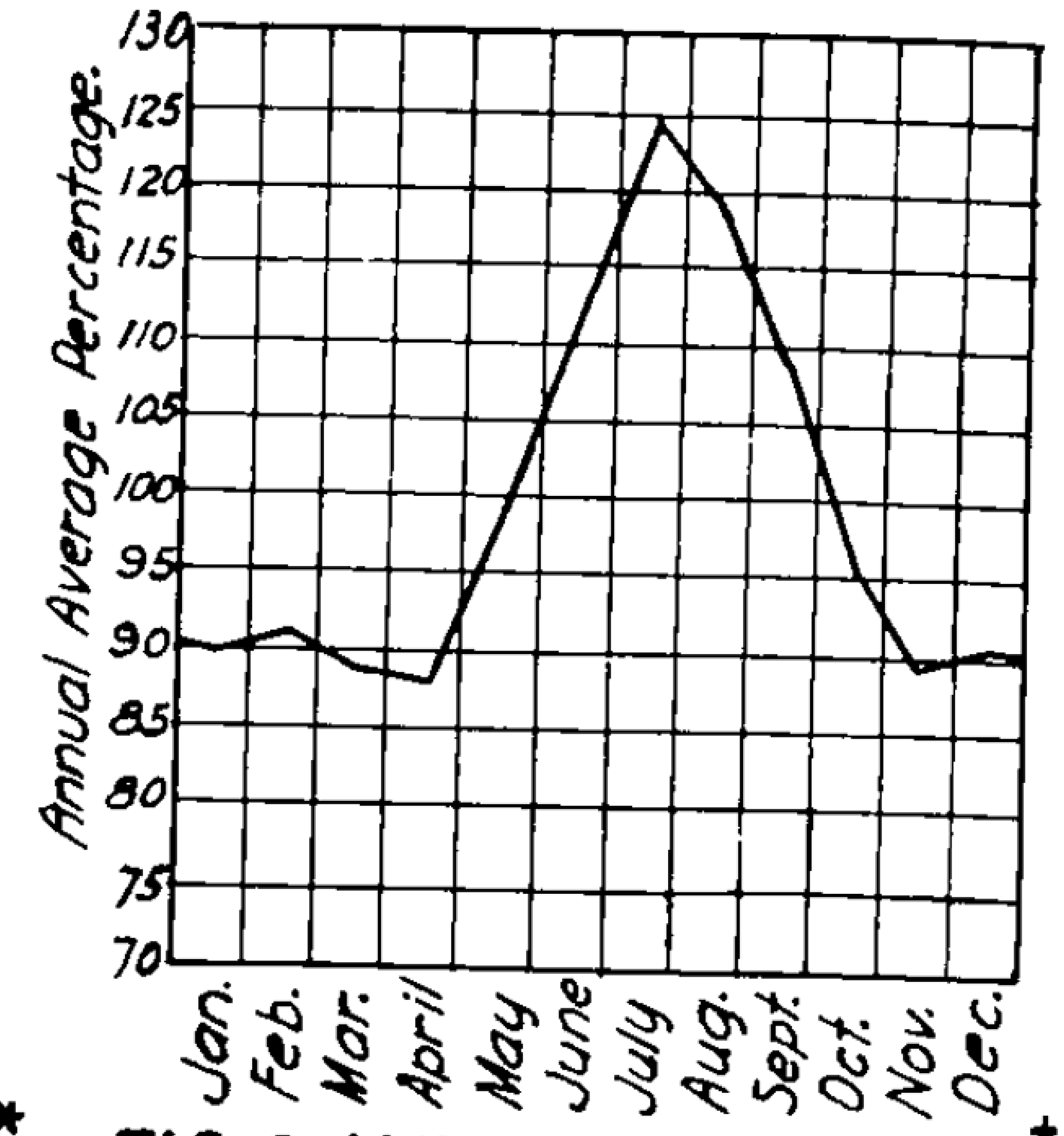


FIG. C-ANNUAL VARIATION† IN MASSACHUSETTS CITIES.

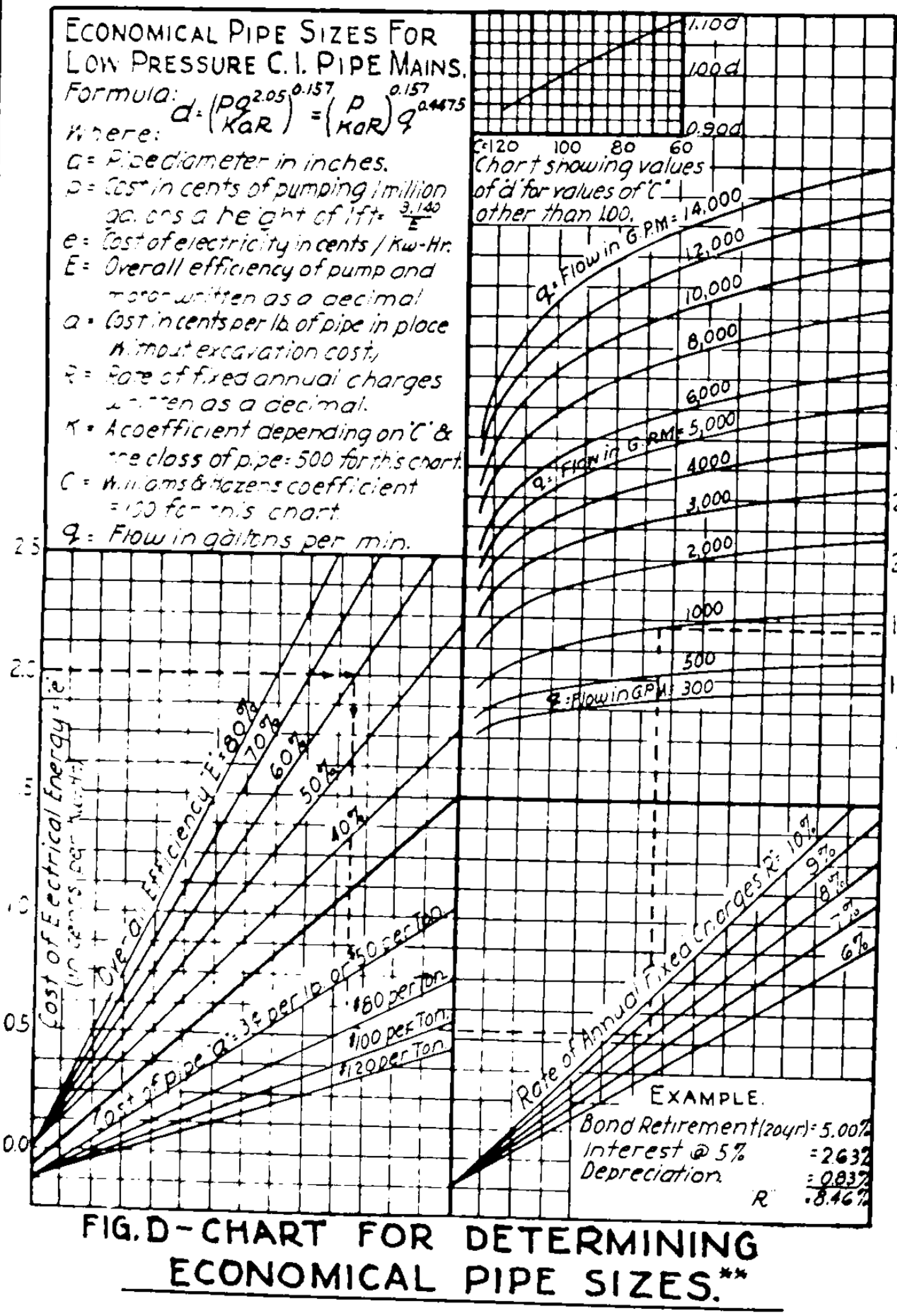


FIG. D-CHART FOR DETERMINING ECONOMICAL PIPE SIZES.**

ESSENTIALS FOR DESIGN OF PUMPING STATIONS.

1. Investigate use or construction of storage tanks or reservoirs to allow uniform rates of pumping for long periods of the day.
2. Provide different capacity pumps to obtain maximum efficiencies for variations of demand.
3. Provide in duplicate largest pump and motor unit.
4. Provide auxiliary power units (Generally gasoline or Diesel) to meet maximum combined fire and domestic draft.
5. Design for no suction lift if possible.
6. Provide a separate suction intake for each pump if possible. If not, provide tapering header with "Y" branches.
7. Provide eccentric increasers on suction side of pump, if increasers are necessary. Provide exactly horizontal suction pipe, or slope down to intake. Avoid high spots in suction pipe to prevent air entrapment.
8. Provide flexible couplings to facilitate placing and replacing flanged pipe.
9. Provide check valves on discharge side of each pump and gate valves on both sides of each pump.
10. All equipment accessible to an overhead crane or arranged so that it can be removed and replaced without disturbing other pieces of equipment.
11. Provide tie rods and thrust blocks for pipe.
12. Provide a fireproof, well lighted and ventilated building.

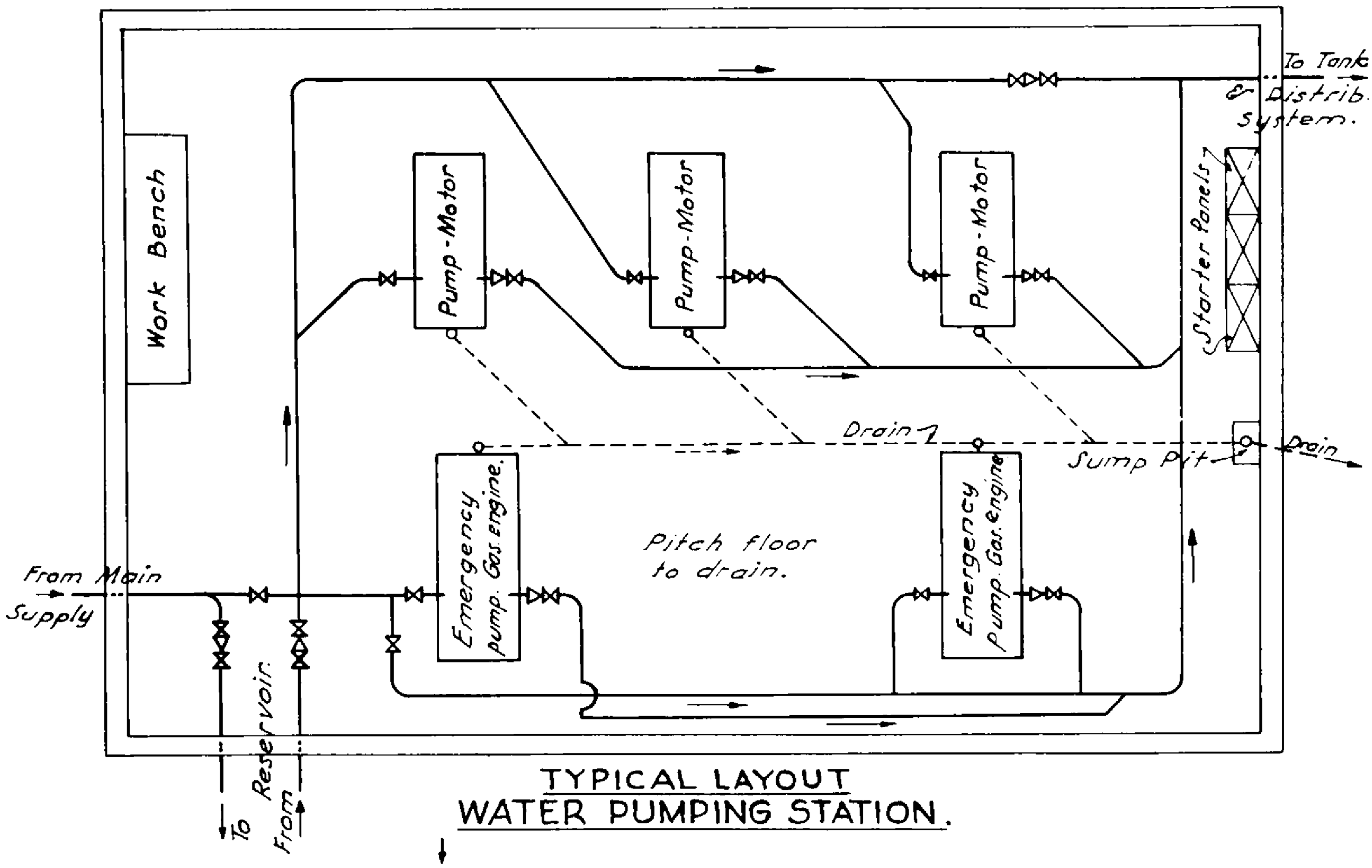
† From Journal of N.E.W.W.A. Vol. 27 Page 85, 1913

* Data From Flynn, Weston & Bogert, Waterworks Handbook, McGraw-Hill.

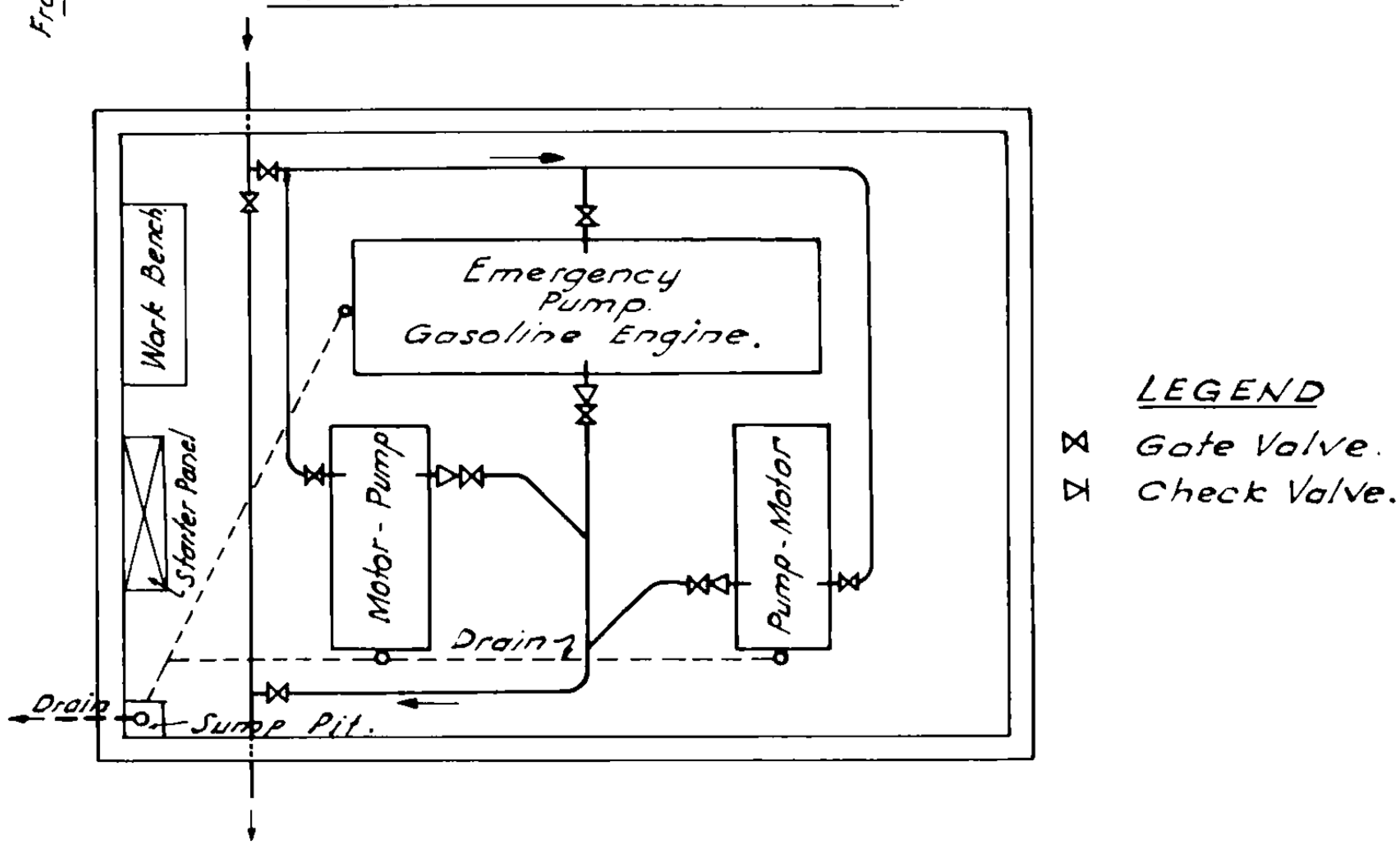
** Chart from Cameron Handbook of Hydraulic Data, Courtesy of Geo. B. Gascoigne.

WATER SUPPLY – PUMPING STATIONS

Essentials for Design of Pumping Stations - See Pg. 6-12.



TYPICAL LAYOUT
WATER PUMPING STATION.



TYPICAL LAYOUT
WATER BOOSTER PUMPING STATION.

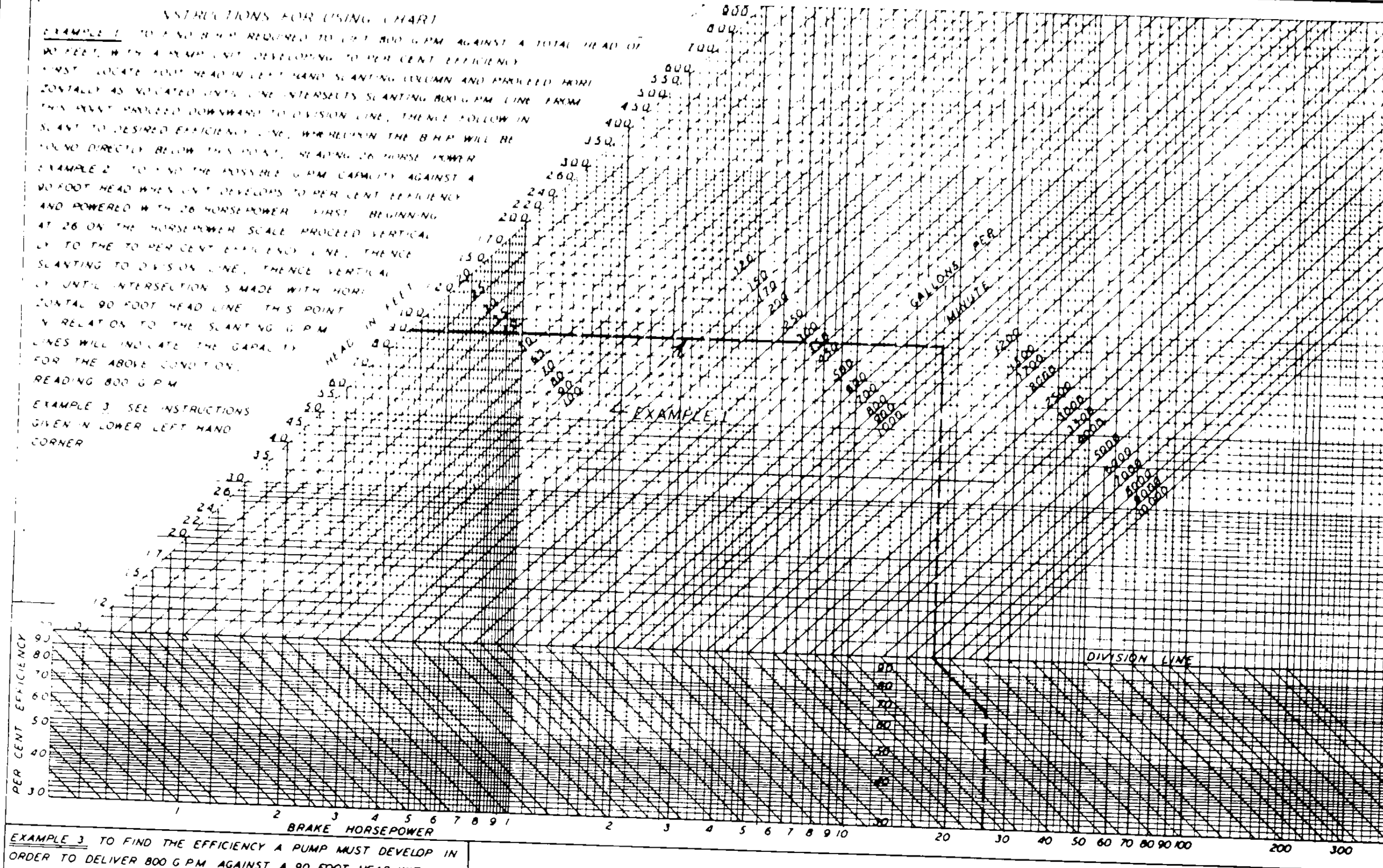
WATER SUPPLY — PUMP HORSEPOWER

INSTRUCTIONS FOR USING CHART

EXAMPLE 1. TO FIND B.H.P. REQUIRED TO GET 800 G.P.M. AGAINST A TOTAL HEAD OF 90 FEET, WITH A PUMP UNIT DEVELOPING 70 PER CENT EFFICIENCY. FIRST LOCATE FOOT HEAD IN LEFT HAND SLANTING COLUMN AND PROCEED HORIZONTALLY AS INDICATED UNTIL LINE INTERSECTS SLANTING 800 G.P.M. LINE. FROM THIS POINT PROCEED DOWNWARD TO DIVISION LINE, THENCE FOLLOW IN SLANT TO DESIRED EFFICIENCY LINE, WHEREUPON THE B.H.P. WILL BE FOUND DIRECTLY BELOW THIS POINT, READING 26 HORSE POWER.

EXAMPLE 2. TO FIND THE POSSIBLE G.P.M. CAPACITY AGAINST A 90 FOOT HEAD WHEN UNIT DEVELOPS 70 PER CENT EFFICIENCY AND POWERED WITH 26 HORSEPOWER. FIRST BEGINNING AT 26 ON THE HORSEPOWER SCALE PROCEED VERTICALLY TO THE 70 PER CENT EFFICIENCY LINE, THENCE SLANTING TO DIVISION LINE, THENCE VERTICALLY UNTIL INTERSECTION IS MADE WITH HORIZONTAL 90 FOOT HEAD LINE. THIS POINT IN RELATION TO THE SLANTING G.P.M. LINES WILL INDICATE THE CAPACITY FOR THE ABOVE CONDITION, READING 800 G.P.M.

EXAMPLE 3. SEE INSTRUCTIONS GIVEN IN LOWER LEFT HAND CORNER



EXAMPLE 3. TO FIND THE EFFICIENCY A PUMP MUST DEVELOP IN ORDER TO DELIVER 800 G.P.M. AGAINST A 90 FOOT HEAD WITH 26 HORSEPOWER PROCEED AS IN EXAMPLE 1 TO DIVISION LINE, THEN SLANTWISE UNTIL INTERSECTION IS MADE WITH THE VERTICAL 26 HORSEPOWER LINE. THIS POINT WILL LOCATE THE HORIZONTAL EFFICIENCY LINE, READING 70 PER CENT

Chart for Determining Head, Capacity, Efficiency, Horse Power With Any Three Conditions Known

(From the Peerless Pump Bulletin)

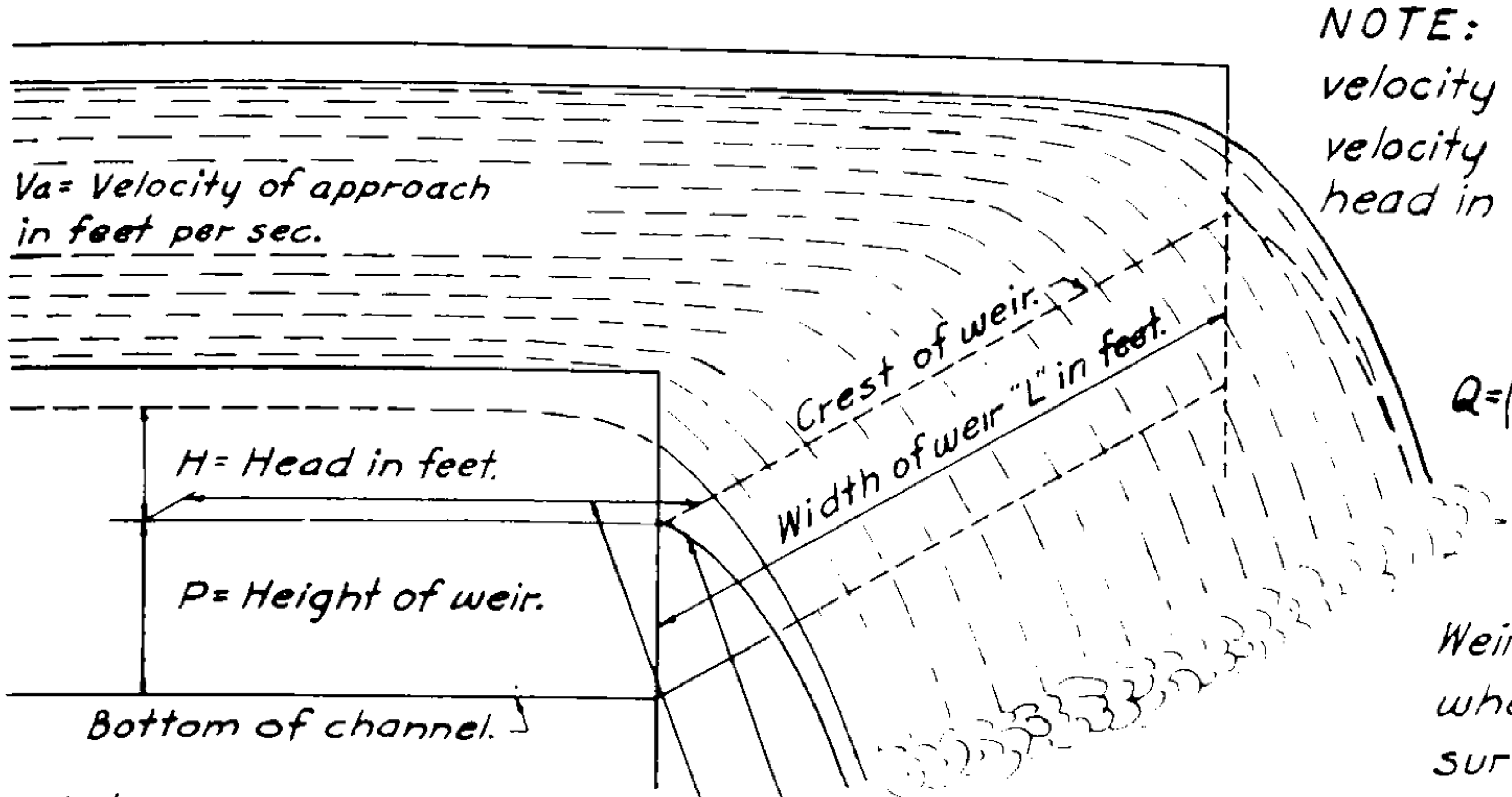
$$\text{Brake H.P. required} = \frac{\text{G.P.M.} \times \text{Feet Head}}{3960 \times \text{Pump Eff.}}$$

1 Kilowatt = 1.34 H.P.

1 H.P. = 550 Foot Pounds / Sec. = 33,000 Foot Pounds / Min.

Standard Motor Sizes in H.P. — $\frac{1}{6}$, $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$, 2, 3, 5, $7\frac{1}{2}$, 10, 15, 20, 25, 30, 40, 50, 60, 75, 100, 125, 150, 200, 250, 300.

WATER SUPPLY-RECTANGULAR WEIR



Point where head is measured should be at least 4xH.

This space below overfall (nappe) must have free admission of air. A partial vacuum would increase discharge.

NOTE: Weir tables assume no velocity of approach. To correct for velocity of approach add $\frac{V_a^2}{2g}$ to head in feet.

(where $g = 32.17$)

Bazins Formula.

$$Q=\left[0.405+\frac{0.00984}{H}\right]\left[1+0.55\frac{H^2}{(P+H)^2}\right]LH\sqrt{2gH}$$

Weir tables can be used only where downstream water surface is below crest of weir.

DISCHARGE VALUES IN CUBIC FEET PER SEC. PER FOOT OF WIDTH OVER RECTANGULAR SHARP CRESTED SUPPRESSED WEIRS. *

H IN FT.	P=2FT.	P=3FT.	P=4FT.	P=5FT.	P=10FT.	P=20FT.	P=30FT.
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05
0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07
0.08	0.11	0.11	0.11	0.11	0.11	0.11	0.11
0.10	0.13	0.13	0.13	0.13	0.13	0.13	0.13
0.12	0.17	0.17	0.17	0.17	0.17	0.17	0.17
0.14	0.21	0.21	0.21	0.21	0.21	0.21	0.21
0.16	0.25	0.25	0.25	0.25	0.25	0.25	0.25
0.18	0.29	0.29	0.29	0.29	0.29	0.29	0.29
0.20	0.33	0.33	0.33	0.33	0.33	0.33	0.33
0.22	0.38	0.38	0.38	0.38	0.38	0.38	0.38
0.24	0.43	0.43	0.43	0.43	0.43	0.43	0.43
0.26	0.48	0.48	0.48	0.48	0.48	0.48	0.48
0.28	0.53	0.53	0.53	0.53	0.53	0.53	0.53
0.30	0.58	0.58	0.58	0.58	0.58	0.58	0.58
0.32	0.64	0.64	0.64	0.64	0.64	0.64	0.62
0.34	0.70	0.70	0.70	0.70	0.70	0.69	0.68
0.36	0.76	0.76	0.76	0.76	0.76	0.75	0.74
0.38	0.82	0.82	0.82	0.82	0.81	0.81	0.80
0.40	0.88	0.88	0.88	0.87	0.87	0.87	0.87
0.45	1.06	1.06	1.05	1.05	1.04	1.04	1.03
0.50	1.23	1.22	1.21	1.21	1.21	1.20	1.20
0.55	1.42	1.40	1.39	1.39	1.39	1.39	1.39
0.60	1.62	1.59	1.59	1.58	1.57	1.57	1.57
0.70	2.04	2.01	1.99	1.98	1.97	1.97	1.97
0.80	2.50	2.45	2.43	2.42	2.40	2.40	2.40
0.90	3.00	2.93	2.90	2.88	2.86	2.85	2.85
1.00	3.53	3.44	3.40	3.38	3.34	3.33	3.33
1.10	4.09	3.98	3.92	3.91	3.85	3.84	3.84
1.20	4.68	4.55	4.48	4.47	4.38	4.36	4.36
1.30	5.31	5.15	5.07	5.05	4.94	4.91	4.91
1.40	5.99	5.78	5.68	5.62	5.52	5.49	5.48
1.50	6.68	6.44	6.30	6.23	6.13	6.10	6.09

H IN FT.	P=2FT.	P=3FT.	P=4FT.	P=5FT.	P=10FT.	P=20FT.	P=30FT.
1.60	7.40	7.12	6.97	6.89	6.74	6.69	6.69
1.70	8.14	7.83	7.66	7.56	7.39	7.33	7.32
1.80	8.93	8.56	8.37	8.25	8.05	7.98	7.96
1.90	9.75	9.32	9.11	8.97	8.74	8.65	8.63
2.00	10.58	10.12	9.87	9.72	9.44	9.34	9.32
2.10	11.45	10.93	10.65	10.48	10.17	10.05	10.02
2.20	12.34	11.77	11.46	11.27	10.91	10.78	10.75
2.30	13.24	12.64	12.29	12.07	11.66	11.52	11.48
2.40	14.20	13.53	13.15	12.91	12.45	12.28	12.24
2.50	15.17	14.45	14.03	13.76	13.26	13.06	13.01
2.60	16.16	15.38	14.92	14.63	14.07	13.85	13.80
2.70	17.18	16.34	15.83	15.52	14.92	14.65	14.60
2.80	18.23	17.32	16.79	16.44	15.76	15.48	15.42
2.90	19.29	18.32	17.77	17.36	16.63	16.33	16.25
3.00	20.39	19.36	18.74	18.33	17.52	17.18	17.10
3.10	21.50	20.40	19.74	19.31	18.42	18.04	17.96
3.20	22.64	21.48	20.77	20.31	19.34	18.93	18.83
3.30	23.81	22.59	21.80	21.33	20.27	19.82	19.73
3.40	24.98	23.70	22.89	22.36	21.24	20.75	20.63
3.50	26.20	24.83	24.00	23.43	22.22	21.69	21.60
3.60	27.41	25.99	25.09	24.49	23.20	22.62	22.48
3.70	28.64	27.17	26.22	25.59	24.20	23.59	23.43
3.80	29.94	28.38	27.38	26.70	25.23	24.56	24.39
4.00	32.54	30.84	29.74	28.99	27.32	26.55	26.35
4.20	35.22	33.39	32.18	31.35	29.48	28.59	28.36
4.40	37.99	36.01	34.70	33.78	31.70	30.66	30.42
4.60	40.83	38.71	37.29	36.29	33.98	32.84	32.53
4.80	43.75	41.49	39.96	38.87	36.33	35.05	34.70
5.00	46.71	44.31	42.67	41.49	38.70	37.28	36.88
5.20	49.81	47.27	45.50	44.23	41.20	39.61	39.17
5.40	52.94	50.23	48.38	47.02	43.71	41.96	41.47
5.60	56.15	53.33	51.34	49.88	46.31	44.38	43.83
5.80	59.42	56.45	54.34	52.79	48.94	46.83	46.22
6.00	62.77	59.65	57.43	55.78	51.64	49.34	48.67

* Data from Hydraulic Tables by Hazen and Williams.

WATER SUPPLY-ORIFICES & WEIRS

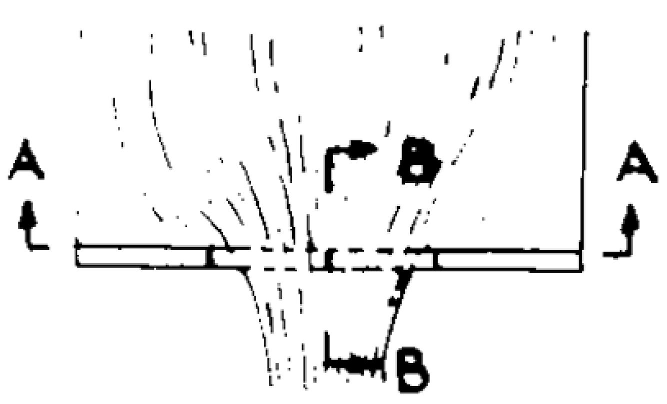
DISCHARGE OVER 90° TRIANGULAR V NOTCH SHARP CRESTED WEIR*

(COMMONLY USED WHERE FLOWS ARE SMALL.)

Thompson Formula

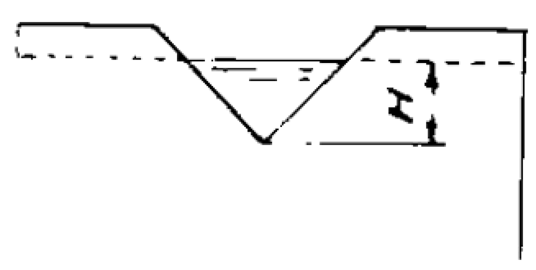
$Q = 2.54 H^{5/2}$

For general notes see drawing of rectangular weir.

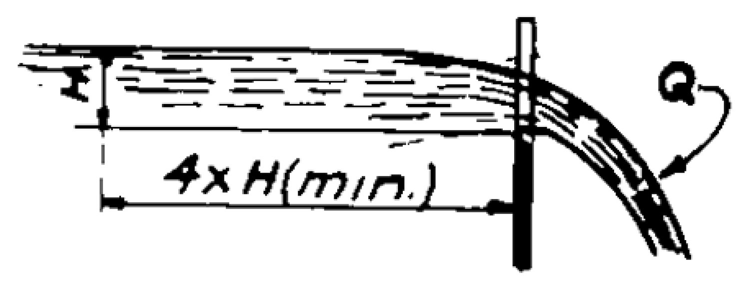


PLAN

Q = Discharge in cu. ft. per sec.
H = Head in feet.



SECTION A-A



SECTION B-B

H IN FEET	H IN INCHES	Q IN CU. FT. PER SEC.
0.05	5/8	0.0015
0.10	1 3/16	0.0085
0.15	2 3/8	0.022
0.20	2 3/8	0.473
0.30	3 5/8	0.129
0.40	4 13/16	0.262
0.50	6	0.455
0.60	7 3/16	0.714
0.70	8 3/8	1.044
0.80	9 5/8	1.452
0.90	10 13/16	1.943
1.00	12	2.520
1.10	13 3/16	3.189
1.20	14 3/8	3.954
1.30	15 5/8	4.818
1.40	16 13/16	5.785
1.50	18	6.860

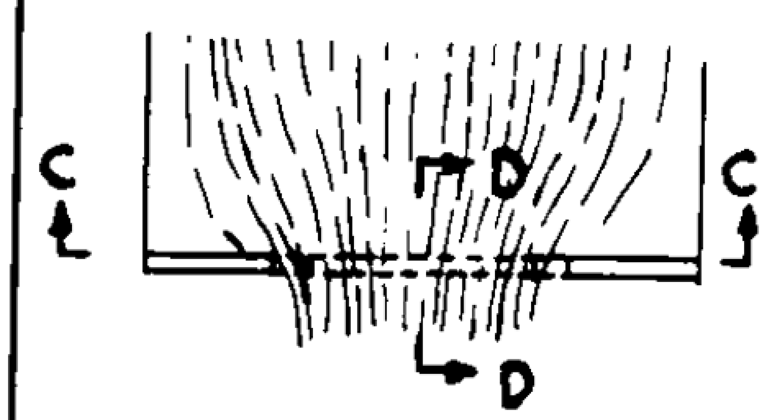
DISCHARGE PER FOOT OF WEIR WIDTH OVER CIPOLLETTI WEIR*

(COMMONLY USED WHERE END CONTRACTION CONDITIONS EXIST.)

Cipolletti Formula

$Q = 3.367 L H^{3/2}$

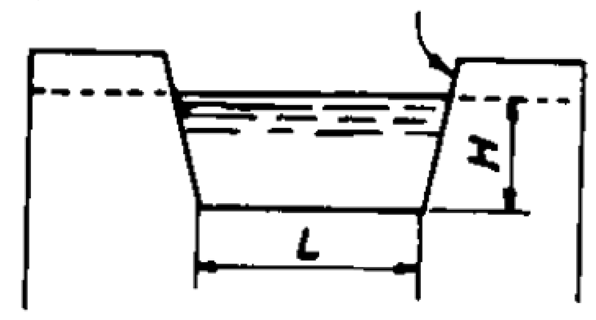
For general notes see drawing of rectangular weir.



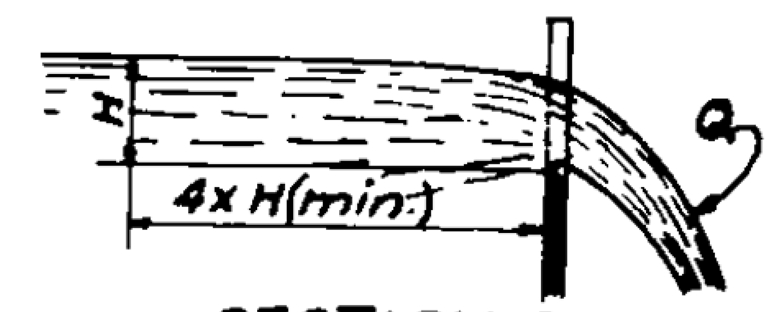
PLAN

Slope 1-Hor. to 4-Vert.

Q = Discharge in cu. ft. per sec.
L = Width of weir in feet.
H = Head in feet.



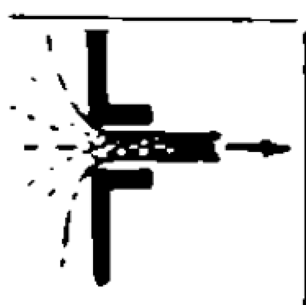
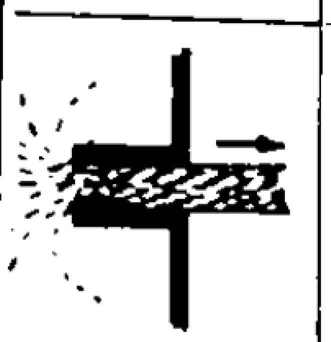
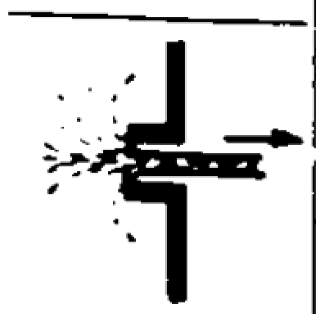
SECTION C-C

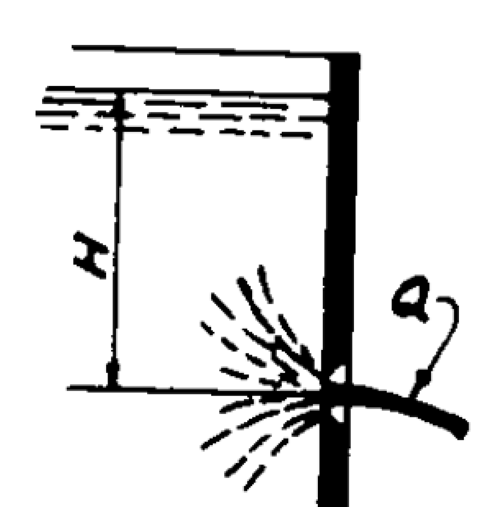


SECTION D-D

H IN FEET	Q IN CU. FT./SEC. PER FT. OF WEIR	H IN FEET	Q IN CU. FT./SEC. PER FT. OF WEIR
0.1	0.107	1.6	6.814
0.2	0.301	1.7	7.462
0.3	0.553	1.8	8.130
0.4	0.852	1.9	8.817
0.5	1.190	2.0	9.522
0.6	1.565	2.1	10.245
0.7	1.972	2.2	10.986
0.8	2.409	2.3	11.743
0.9	2.875	2.4	12.517
1.0	3.367	2.5	13.308
1.1	3.884	2.6	14.114
1.2	4.426	2.7	14.936
1.3	4.990	2.8	15.774
1.4	5.577	2.9	16.626
1.5	6.185	3.0	17.494

DISCHARGE THROUGH AN ORIFICE OR TUBE

Diagram	Description	Average discharge coefficient, C_d
	**SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY** When the stream springs clear from the tube at the upstream corner the flow is the same as for a sharp-edged orifice.	0.61
	**RE-ENTRANT TUBE** Length about 2½ diameters. Flowing full.	0.73
	**RE-ENTRANT TUBE** When the length is about one diameter it is called "Borda's Mouthpiece". Stream springs clear of the walls of the tube.	0.52

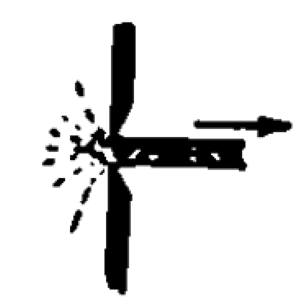
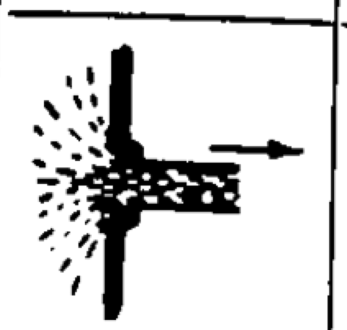
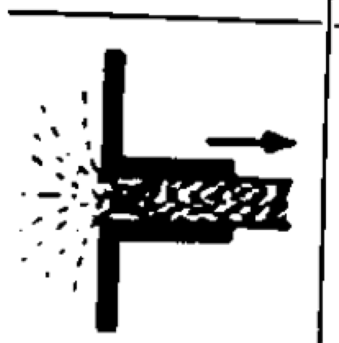


H = Head in ft. on center of orifice
Q = Discharge in cu. ft./sec.

Orifice Formula.

$Q = C_d A \sqrt{2gH}$

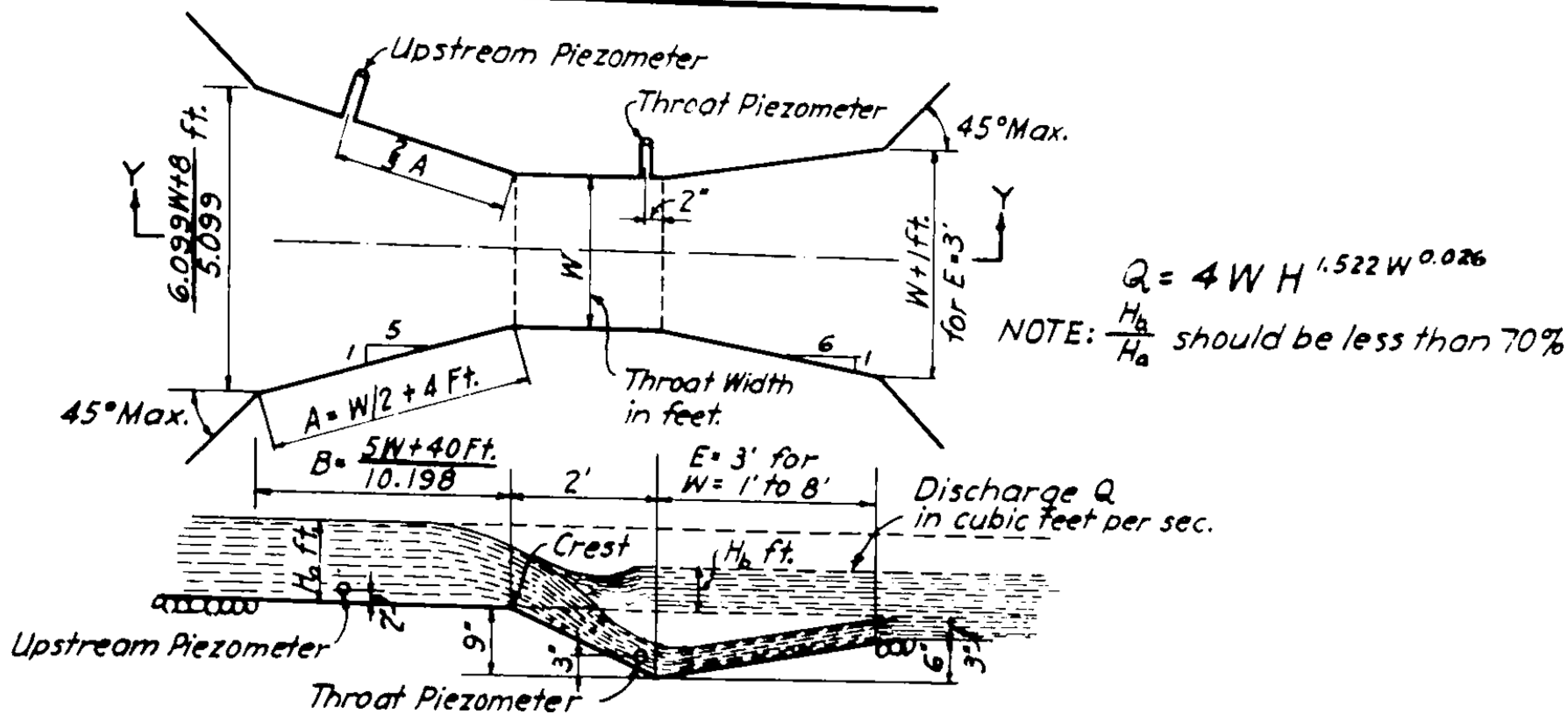
A = Area of orifice in sq. ft.
Cd = Discharge coefficient.
g = 32.17

Diagram	Description	Average discharge coefficient, C_d
	**SHARP-EDGED ORIFICE** The stream is contracted to about 0.62 of the area of the opening.	0.61
	**ORIFICE WITH WELL-ROUNDED ENTRY** There is little or no contraction and the stream is about the same size as the opening.	0.98
	**SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY** When flowing full. When the length of the tube is 2½ diameters it is called a "standard short tube".	0.82

**Adapted from Handbook of Water Control by the California Corrugated Culvert Co.*

WATER SUPPLY - PARSHALL FLUME

PARSHALL FLUME*



SECTION Y-Y

TABLE A - DISCHARGE THROUGH PARSHALL FLUMES.**

UPPER HEAD Ha (FT.)	DISCHARGE IN CUBIC FEET PER SECOND — THROAT WIDTH W IN FEET: 1	2	3	4	5	6	7	8
0.20	0.35	0.66	0.97	1.26				
0.25	0.49	0.93	1.37	1.80	2.22	2.63		
0.30	0.64	1.24	1.82	2.39	2.96	3.52	4.08	4.62
0.35	0.80	1.57	2.32	3.06	3.78	4.50	5.22	5.93
0.40	0.99	1.93	2.86	3.77	4.68	5.57	6.46	7.34
0.45	1.19	2.32	3.44	4.54	5.63	6.72	7.80	8.87
0.50	1.39	2.73	4.05	5.36	6.66	7.94	9.23	10.5
0.55	1.62	3.17	4.70	6.23	7.74	9.25	10.8	12.2
0.60	1.84	3.62	5.39	7.15	8.89	10.6	12.4	14.1
0.65	2.08	4.11	6.12	8.11	10.1	12.1	14.1	16.0
0.70	2.33	4.60	6.86	9.11	11.4	13.6	15.8	18.0
0.75	2.58	5.12	7.65	10.2	12.7	15.2	17.7	20.1
0.80	2.85	5.66	8.46	11.3	14.0	16.8	19.6	22.4
0.85	3.12	6.22	9.30	12.4	15.5	18.5	21.6	24.6
0.90	3.41	6.80	10.2	13.6	16.9	20.3	23.7	27.0
0.95	3.70	7.39	11.1	14.8	18.4	22.1	25.8	29.5
1.00	4.00	8.00	12.00	16.00	20.00	24.00	28.0	32.0
1.05	4.31	8.63	13.0	17.3	21.6	25.9	30.3	34.6
1.10	4.62	9.27	13.9	18.6	23.3	27.9	32.6	37.3
1.15	4.94	9.94	14.9	19.9	25.0	30.0	35.0	40.1
1.20	5.28	10.6	16.0	21.3	26.7	32.1	37.5	42.9
1.25	5.62	11.3	17.0	22.8	28.5	34.3	40.0	45.8
1.30	5.96	12.0	18.1	24.2	30.3	36.5	42.6	48.6

UPPER HEAD Ha (FT.)	DISCHARGE IN CUBIC FEET PER SECOND — THROAT WIDTH W IN FEET: 1	2	3	4	5	6	7	8
1.35	6.32	12.7	19.2	25.7	32.2	38.7	45.3	51.8
1.40	6.68	13.5	20.3	27.2	34.1	41.1	48.0	55.0
1.45	7.04	14.2	21.3	28.8	36.1	43.4	50.8	58.1
1.50	7.41	15.0	22.6	30.3	38.1	45.8	53.6	
1.55	7.80	15.8	23.8	32.0	40.1	48.3	56.5	
1.60	8.18	16.6	25.1	33.6	42.2	50.8	59.4	
1.65	8.57	17.4	26.3	35.3	44.3	53.3		
1.70	8.97	18.2	27.6	37.0	46.4	56.0		
1.75	9.38	19.0	28.8	38.7	48.6	58.6		
1.80	9.79	19.9	30.1	40.5	50.8			
1.85	10.2	20.8	31.5	42.2	53.1			
1.90	10.6	21.6	32.8	44.1	55.4			
1.95	11.1	22.5	34.1	45.9	57.7			
2.00	11.5	23.4	35.5	47.8	60.1			
2.05	11.9	24.3	36.9	49.7				
2.10	12.4	25.3	38.4	51.6				
2.15	12.8	26.2	39.8	53.5				
2.20	13.3	27.2	41.3	55.5				
2.25	13.7	28.1	42.7	57.5				
2.30	14.2	29.1	44.2	59.6				
2.35	14.7	30.1	45.7					
2.40	15.2	31.1	47.3					
2.50	16.1	33.1	50.4					

* Adapted from Schoder & Dawson, Hydraulics, McGraw-Hill
** Table from Handbook of Water Control by The California Corrugated Culvert Co.

WATER SUPPLY - DRINKING WATER REQUIREMENTS[§]-1

1. Turbidity (silica scale) * . . . . 10 p.p.m. max.
2. Color (standard cobalt scale) * . . . . 20 max.
3. Taste or odor * . . . . None
4. Lead * . . . . 0.1 p.p.m. max.
5. Fluoride * . . . . 1.0 p.p.m. max.
6. Arsenic * . . . . 0.05 p.p.m. max.
7. Selenium * . . . . 0.05 p.p.m. max.
8. Salts of barium, hexavalent chromium, heavy metal glucosides * . . . . None
9. Copper ** . . . . 3.0 p.p.m. max.
10. Iron & manganese (together) ** . . . . 0.3 p.p.m. max.
11. Magnesium ** . . . . 125 p.p.m. max.
12. Zinc ** . . . . 15 p.p.m. max.
13. Chloride ** . . . . 250 p.p.m. max.
14. Sulphate ** . . . . 250 p.p.m. max.
15. Phenolic compounds (in terms of phenol)** . . . . 0.001 p.p.m. max.
16. Total solids ** . . . . 500-1000 p.p.m. max.
17. Alkalinity (calculated as $CaCO_3$) **
    a. Waters softened by lime-soda process . . . . a. Total alkalinity produced by the process should not exceed the original hardness by more than 35 p.p.m.
    b. Waters treated chemically . . . . b_1. The phenolphthalein alkalinity should not be greater than 15 p.p.m. plus 0.4 times total alkalinity.†
    b_2. Normal carbonate alkalinity should not exceed 120 p.p.m.††
18. Hardness . . . . No limit on drinking water. Waters with hardness of over 100 to 150 p.p.m. when used for laundries and boilers usually require softening.

Hardness Table

P.P.M.	Degree of Hardness	P.P.M.	Degree of Hardness
15	Extremely soft	130	Hard
30	Very soft	170	Very hard
45	Soft	230	Excessively hard
90	Moderately soft	250	Too hard for use
110	Moderately hard		

19. Residual chlorine * . . . . a. Normally all points in distribution system at least 0.05 to 0.10 p.p.m.
    b. During water-borne disease outbreaks, minimum of 0.2 to 0.3 p.p.m. in all points of distribution system.
20. pH . . . . Should be as close to 7.0 as economically feasible. Waters below 7.0 (acid waters) cause tuberculation. Waters above 7.0 cause incrustation of pipes.

* Excess of amount indicated shall be grounds for rejection of water.

** These chemical substances should preferably not occur in excess of the concentrations given where in the judgment of the certifying authority other more suitable supplies are available.

† Requirement under b_1 limits the permissible pH to about 10.6 at 25°C.

†† Since the normal alkalinity is a function of the hydrogen ion concentration and the total alkalinity, this requirement may be met by keeping the total alkalinity within the limits suggested when the pH of the water is within the range given. These values apply to water at 25°C.

pH Range	Limit for Total Alkalinity (p.p.m. as $CaCO_3$)	pH Range	Limit for Total Alkalinity (p.p.m. as $CaCO_3$)
8.0 to 9.6	400	10.1	210
9.7	340	10.2	190
9.8	300	10.3	180
9.9	260	10.4	170
10.0	230	10.5 to 10.6	160

[§] Adapted from Standards of the U.S. Public Health Service, 1942.

WATER SUPPLY - DRINKING WATER REQUIREMENTS*-2

10 Milliliter Portion	100 Milliliter Portion
1. Of all portions tested in one month maximum allowable number of portions showing *B. coli* (+) is 10%.	1. Of all portions tested in one month maximum allowable number of portions showing *B. coli* (+) is 60%.
2. Occasionally 3 or more of the 5 portions of a sample may show *B.coli* (+). This is acceptable except if it occurs in: (a) Consecutive samples. (b) More than 5% of the standard samples when 20 or more samples have been examined per month. (c) More than 1 standard sample when less than 20 samples have been examined per month.	2. Occasionally all 5 portions of a sample may show *B. coli* (+). This is acceptable except if it occurs in: (a) Consecutive samples. (b) More than 20% of the standard samples when 5 or more samples have been examined per month. (c) More than 1 standard sample when less than 5 samples have been examined per month.
3. When condition 2 exists, daily samples shall be taken and examined until the results from 2 consecutive samples show the water to be satisfactory. With water of unknown quality under condition 2, simultaneous tests should be made on portions of 10 milliliters, 1 milliliter, and 0.1 milliliter.	3. When condition 2 exists, daily samples shall be taken and examined until the results from 2 consecutive samples show the water to be satisfactory. With water of unknown quality under condition 2, simultaneous tests should be made on portions of 100 milliliters, 10 milliliters, and 1 milliliter.

In accordance with the first requirement stated above, namely, that of all the standard 100 milliliter or 10 milliliter portions examined per month in accordance with the specified procedure, not more than 60% or 10% respectively shall show the presence of organisms of coliform group, this may be interpreted as implying that the mean density (most probable number - M.P.N.) of organisms of the coliform group shall not exceed about 1 per 100 milliliters.

By general convention (+) indicates presence of *B.coli* and (-) indicates absence of *B.coli*.

<u>Standard Portion:</u> 10 milliliters or 100 milliliters.

<u>1 Standard Sample</u> = 5 standard portions.

Population Served	Samples Per Month, Min.
2,500 and under	1
10,000	7
25,000	25
100,000	100
1,000,000	300
2,000,000	390
5,000,000	500

<u>Standard Tests for *Coli aerogenes (B.coli)*</u>

1. Presumptive
2. Confirmed
3. Completed

For outline procedure of tests, see Standard Method for the Examination of Water and Sewage, 8th ed., 1936, published by Am.Pub. Health Assoc.

Note: Either confirmed or completed tests are recommended by the Public Health Service for standard methods of testing.

* Adapted from Standards of the U.S. Public Health Service, 1942.

WATER PURIFICATION-EXTENT OF TREATMENT REQUIRED

Group No.	Description	Treatment Required
1	This group limited to underground waters subject to no possibility of contamination, meeting all the requirements of the standards and having a maximum B. coli index of 1.0 per 100 ml. (milliliters) at all times.	Waters requiring no treatment.
2	This group includes underground and surface waters, subject to a low degree of contamination and meeting all the requirements of the standards, except as to coliform bacterial content which should average not more than 50 per 100 ml. in any month.	Waters requiring simple chlorination or its . equivalent.
3	This group includes waters requiring filtration treatment for turbidity and color removal, waters of high or variable chlorine demand* and waters polluted by sewage to an extent such as to be inadmissible to Groups 1 and 2, but containing numbers of coliform bacteria averaging not more than 5,000 per 100 ml. in any month and exceeding this number in not more than 20% of the samples examined in any month.	Waters requiring complete rapid sand filtration treatment or its equivalent, together with continuous post-chlorination.
4	This group includes waters meeting the requirements of Group 3 limiting monthly average coliform numbers, but showing numbers exceeding 5,000 per 100 ml. in more than 20% of the samples examined during any month and not exceeding 20,000 per 100 ml. in more than 5% of the samples examined during any month.	Waters requiring auxiliary treatment in addition to complete filtration treatment and post-chlorination.

*Normal demand is usually 0.1 to 1.0 part per million.

Notes: (1) By "auxiliary treatment" is meant presedimentation or prechlorination or their equivalents, either separately or combined. Long-time storage, for periods of 30 days or more, provides a permanent and reliable safeguard, which in many cases offers an effective substitute for presedimentation and prechlorination.

(2) Waters failing to meet the requirements of Groups 1, 2, 3 or 4 are considered as unsuitable for use as a source of water supply, unless they are brought into conformance with these requirements by means of prolonged preliminary storage.

Adapted from Standards of the U.S. Public Health Service, 1942.

WATER PURIFICATION-STORAGE RESERVOIR TREATMENT

TABLE A - APPROXIMATE CONCENTRATIONS OF COPPER SULPHATE TO KILL VARIOUS MICROORGANISMS[1].

Organism	Taste and Odor	Parts per Million Copper Sulphate
Diatoms		
Asterionella	Aromatic, geranium, fishy	0.12-0.20
Cyclotella	Faintly aromatic	
Fragilaria		0.25
Melosira		0.20
Navicula		0.07
Nitzchia		0.50
Synedra	Earthy	0.36-0.50
Stephanodiscus		0.33
Tabellaria	Aromatic, geranium, fishy	0.12-0.50
Chlorophyceae		
Cladophora		0.50
Closterium		0.17
Coelastrum		0.05-0.33
Conferva		0.25
Desmidium		2.00
Draparnaldia		0.33
Eudorina	Faintly fishy	10.00
Entomophora		0.50
Hydrodictyon	Very offensive	0.10
Miscrospora		0.40
Palmella		2.00
Pandorina	Faintly fishy	10.00
Raphidium		1.00
Scenedesmus		1.00
Spirogyra		0.12
Staurastrum		1.50
Ulothrix		0.20
Volvox	Fishy	0.25
Zygnema		0.50
Cyanophyceae		
Anabaena	Moldy, grassy, vile	0.12
Aphanizomenon	Moldy, grassy, vile	0.12-0.50
Clathrocystis	Sweet, grassy, vile	0.12-0.25
Coelosphaerium	Sweet, grassy	0.20-0.33
Cylindrospermum	Grassy	0.12

Organism	Taste and Odor	Parts per Million Copper Sulphate
Cyanophyceae		
Microcystis		0.20
Oscillaria		0.20-0.50
Rivularia	Moldy, grassy	
Protozoa		
Bursaria	Irish moss, salt marsh, fishy	
Ceratium	Fishy, vile	0.33
Chlamydomonas		0.50
Cryptomonas	Candied violets	0.50
Dinobryon	Aromatic, violets, fishy	0.18
Euglena		0.50
Glenodinium	Fishy	0.50
Mallomonas	Aromatic, violets, fishy	0.50
Peridinium	Fishy	0.50-2.00
Synura	Cucumber, muskmelon, fishy, bitter	0.12-0.25
Uroglena	Fishy, oily, cod-liver	0.05-0.20
Crustacea		
Daphnia		2.00
Schizomycetes		
Beggiatoa	Very offensive decayed	5.00
Cladothrix		0.20
Crenothrix	Very offensive decayed	0.33-0.50
Sphaerotilis natans	Very offensive decayed	0.40
Fungus		
Leptomitus		0.40
Saprolegnia		0.18
Miscellaneous		
Chara		0.10-0.50
Nitella, flexilis	Objectionable	0.10-0.18
Potamogeton		0.30-0.80

TABLE B - CONCENTRATION OF COPPER SULPHATE FATAL TO FISH[1].

Fish	Parts per Million
Trout	0.14
Carp	0.30
Suckers	0.30
Catfish	0.40
Pickerel	0.40
Goldfish	0.50
Perch	0.75
Sunfish	1.20
Black Bass	2.10

TABLE C - AMOUNT OF CHLORINE REQUIRED TO DESTROY MICROSCOPIC ORGANISMS.

Organisms	Test Concentra. of Organisms, Standard Units	Chlorine dose† Parts per Million	Chlorine dose† Lbs. per Million Gallons	Reduction in Organisms, Per Cent	Odors and Tastes Eliminated
Aphanizomenon	1500	0.85	7.1	50	
Cyclotella		1.0	8.3	100	
Melosira	*	2.0	16.6	100	
Crenothrix		0.54	4.5		
Fungi		0.33	2.7		
Dinobryon	500	0.5	4.2	100	Yes
Uroglenopsis	2000	0.5	4.2	100	Yes
	6000	0.5	4.2	100	No‡
Synura	50	0.3	2.5	100	Yes
	100	0.5-0.7	4.2-5.8	100	Yes
	200	>0.7	>5.8	100	Yes
Gnats or blood worms		3.0	24.9	100	

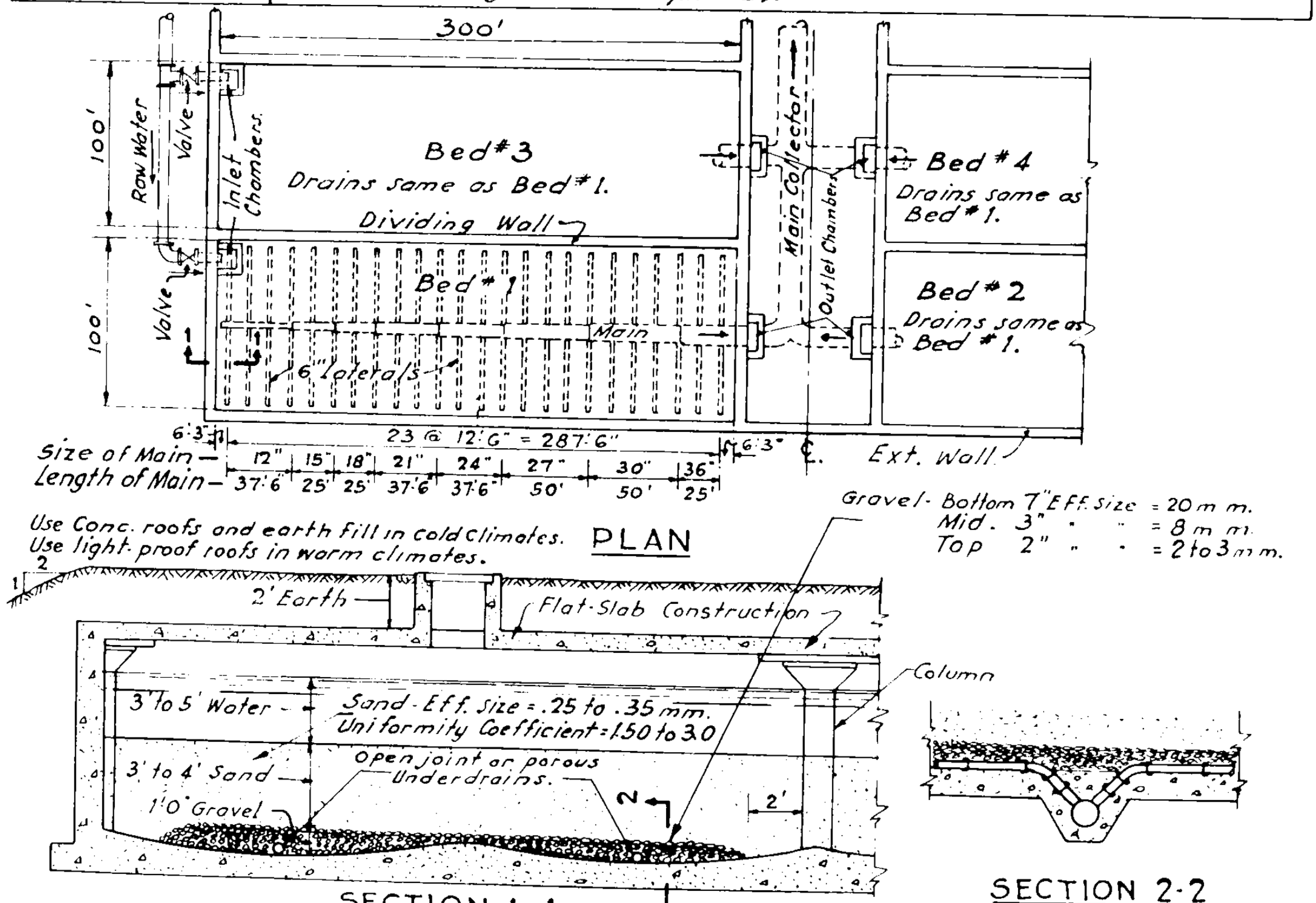
† The amount of chlorine depends somewhat on the chlorine demand of the water.
* Present in sufficient numbers to clog filter.
‡ Taste not noticeable after 10 to 15 miles flow in aqueduct.

Adapted from Manual of Water Quality and Treatment by American Water Works Assoc. 1941.

WATER PURIFICATION — SLOW SAND FILTERS-1

TABLE A - CHARACTERISTICS OF SLOW SAND FILTERS.

Adaptability.	*1. May be economical, if cost of land is low, if raw water load as regards color, bacteria, algae and turbidity is low (see below) and operating costs are important factors (operating costs of slow sand filters generally 1/2 operating costs of rapid sand filters). 2. May be valuable as final process after rapid sand filtration of very polluted waters.*
Capacity.	*2 m.g.d. per acre for highly polluted waters to 10 m.g.d. per acre for water relatively clear or pre-treated by coagulation and sedimentation.*
Efficiency (Bacteria removal).	*98 to 99 % if not overloaded.*
Flexibility.	*Rapid changes in rate not permissible.*
Turbidity limitations.	*Raw water over 100 p.p.m. can not be handled; over 40 p.p.m. may produce unsatisfactory effluent.*
Color limitations.	*Raw water over 30 p.p.m. can not be treated satisfactorily.*
Bed layout.	*Size 1/4 to 1 acre each. Small beds for small plants. Large beds for large plants. No. of units sufficient to allow 1 unit in small plants and 2 in large plants to be out of order and still have plant meet maximum demand (less than 4 units not recommended).*
Flow Regulators.	*Manually operated gates and weirs (no automatic rate of flow controls and measuring devices required).*



SECTION 1-1

SECTION 2-2
AT MAIN DRAIN

FIG. B - DETAIL OF SLOW SAND FILTER - PIPING FOR 1 BED.

WATER PURIFICATION – SLOW SAND FILTERS-2

TABLE A–LOSS OF HEAD IN CLEAN SAND 3' DEEP–TEMP. 50° F. *

Rate of filtration million gals. per acre daily	Effective size of sand—millimeters								
	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60
1	0.10	0.06	0.04	0.03	0.02	0.02	0.02	0.01	0.01
2	0.20	0.13	0.09	0.07	0.05	0.04	0.03	0.03	0.02
3	0.30	0.19	0.13	0.10	0.08	0.06	0.05	0.04	0.03
4	0.40	0.26	0.18	0.13	0.10	0.08	0.06	0.05	0.04
5	0.50	0.32	0.22	0.16	0.12	0.10	0.08	0.07	0.06
6	0.60	0.38	0.27	0.20	0.15	0.12	0.10	0.08	0.07
7	0.70	0.45	0.31	0.23	0.18	0.14	0.11	0.09	0.08
8	0.80	0.51	0.36	0.28	0.20	0.16	0.13	0.11	0.09
9	0.90	0.57	0.40	0.30	0.22	0.18	0.14	0.12	0.10
10	1.00	0.64	0.45	0.33	0.25	0.20	0.16	0.13	0.11
12	1.20	0.77	0.54	0.40	0.30	0.24	0.19	0.16	0.13
14	1.40	0.90	0.63	0.46	0.35	0.28	0.22	0.18	0.15
16	1.60	1.02	0.72	0.53	0.40	0.32	0.26	0.21	0.18
18	1.80	1.15	0.81	0.59	0.45	0.36	0.29	0.24	0.20
20	2.00	1.27	0.89	0.66	0.50	0.40	0.32	0.27	0.22
100	10.02	6.37	4.46	3.28	2.51	1.98	1.61	1.33	1.11
125	12.52	7.96	5.57	4.10	3.13	2.48	2.01	1.67	1.39
150	15.03	9.55	6.69	4.92	3.76	2.97	2.41	1.99	1.67
175	17.54	11.14	7.80	5.74	4.38	3.47	2.81	2.33	1.95
200	20.05	12.74	8.92	6.55	5.01	3.96	3.21	2.65	2.23

NOTES: 1. For loss of head through sand other than the 3' depth shown in Table A, the loss of head varies inversely with the depth.

Example:

Given: Sand depth 40"

Required: Loss of head.

Solution: Loss of head = Value in Table A × $\frac{40}{36}$

2. For temperature other than 50°, loss of head varies as ratio $\frac{60}{°F+10}$.

Example:

Given: Temp. = 70° F.

Required: Loss of head at 70° F.

Solution: Loss of head = Value in Table A × $\frac{60}{70+10}$.

TABLE B–UNDERDRAIN DATA.*

1. Rate of filtration, million gallons per acre daily	5	6	8	10	15
2. Average resistance of clean sand in feet	0.150	0.180	0.240	0.300	0.450
3. Total allowable friction and velocity head in underdrainage system, feet	0.037	0.045	0.060	0.075	0.112
4. Approximate ratio of filter area to area of main drain	5100	4700	4200	3800	3200
5. Approximate maximum velocity in main drain (varying somewhat with size), ft. per sec	0.90	1.00	1.18	1.34	1.68
6. Approximate maximum velocity in laterals (varying somewhat with size), ft. per sec	0.55	0.61	0.72	0.82	1.04

Note: Values on line 3 are 25% of line 2.

UNDERDRAINS

1. Size of underdrains to be such that loss of head in underdrains equals 25% of loss of head through sand. Neglect loss of head through gravel.

2. Underdrains can be laid out using Table C. Check velocities, using maximum velocities indicated in Table B.

TABLE C–MAXIMUM AREAS OF FILTER BEDS DRAINED, SQ. FT. *

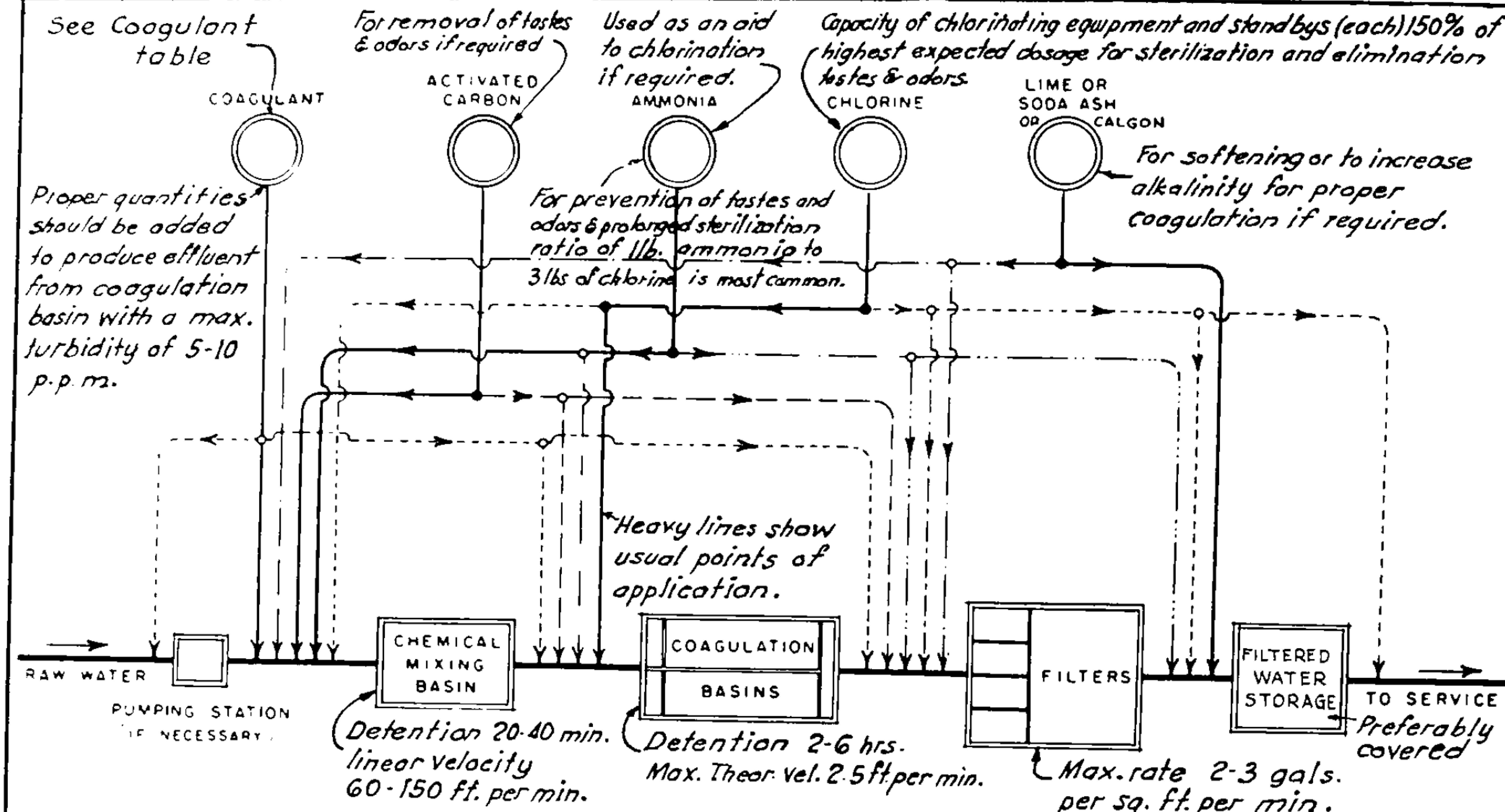
Diameter of drain, inches	Shape and kind of drain	Rate of filtration, million gallons per acre per day				
		5	6	8	10	15
4	Round lateral	264	245	218	200	168
5	Round lateral	420	390	345	316	266
6	Round lateral	610	570	500	460	390
8	Split lateral	520	490	430	400	320
10	Split lateral	830	770	680	630	530
12	Split lateral	1,200	1,120	1,000	910	770
10	Round main	2,700	2,500	2,200	2,000	1,700
12	Round main	3,900	3,600	3,200	2,900	2,400
15	Round main	6,200	5,800	5,100	4,600	3,900
18	Round main	9,000	8,300	7,400	6,700	5,600
21	Round main	12,300	11,400	10,000	9,100	7,600
24	Round main	16,100	14,900	13,200	12,000	10,000
36	Round main	37,000	34,000	30,000	27,000	22,000

NOTE: Since 1923, few slow sand filters have been constructed in the U.S.A. However, this type of filter is adaptable to warm climates, where covers are not required to protect them from freezing in winter, and slow sand filters also have the following advantages over rapid sand filters: Less loss of head, simpler mechanism, requiring less expert supervision, and higher bacterial efficiency without use of disinfectant. It is believed that with careful study of local conditions by Engineers, an increasing number of slow sand filters may be built in the future.

* From Flinn, Weston & Bogert, Waterworks Handbook, Mc Graw-Hill.

WATER PURIFICATION - RAPID SAND FILTER-1

FIG. A- FLOW DIAGRAM FOR MODERN RAPID SAND FILTER PLANT.*



Plant capacity to equal average daily demand if filtered water storage is large and provides for maximum demand. If filtered water storage is small, plant capacity to be 150 to 225% of average daily demand.

TABLE B - COAGULANTS.*

COAGULANTS (IN ORDER OF MOST COMMON USAGE)	APPROX. pH RANGE FOR GOOD COAGULATION
Aluminum Sulphate	5.5 - 8.0
Ferrous Sulphate	8.5 - 11.0
Ferric Sulphate	5.0 - 11.0
Ferric Chloride	5.0 - 11.0
Aluminum Sulphate & Sodium Aluminate	6.0 - 8.5
Sodium Aluminate & Magnesium Hydroxide	10.3 - 10.8
Aluminum Chloride	5.5 - 8.0

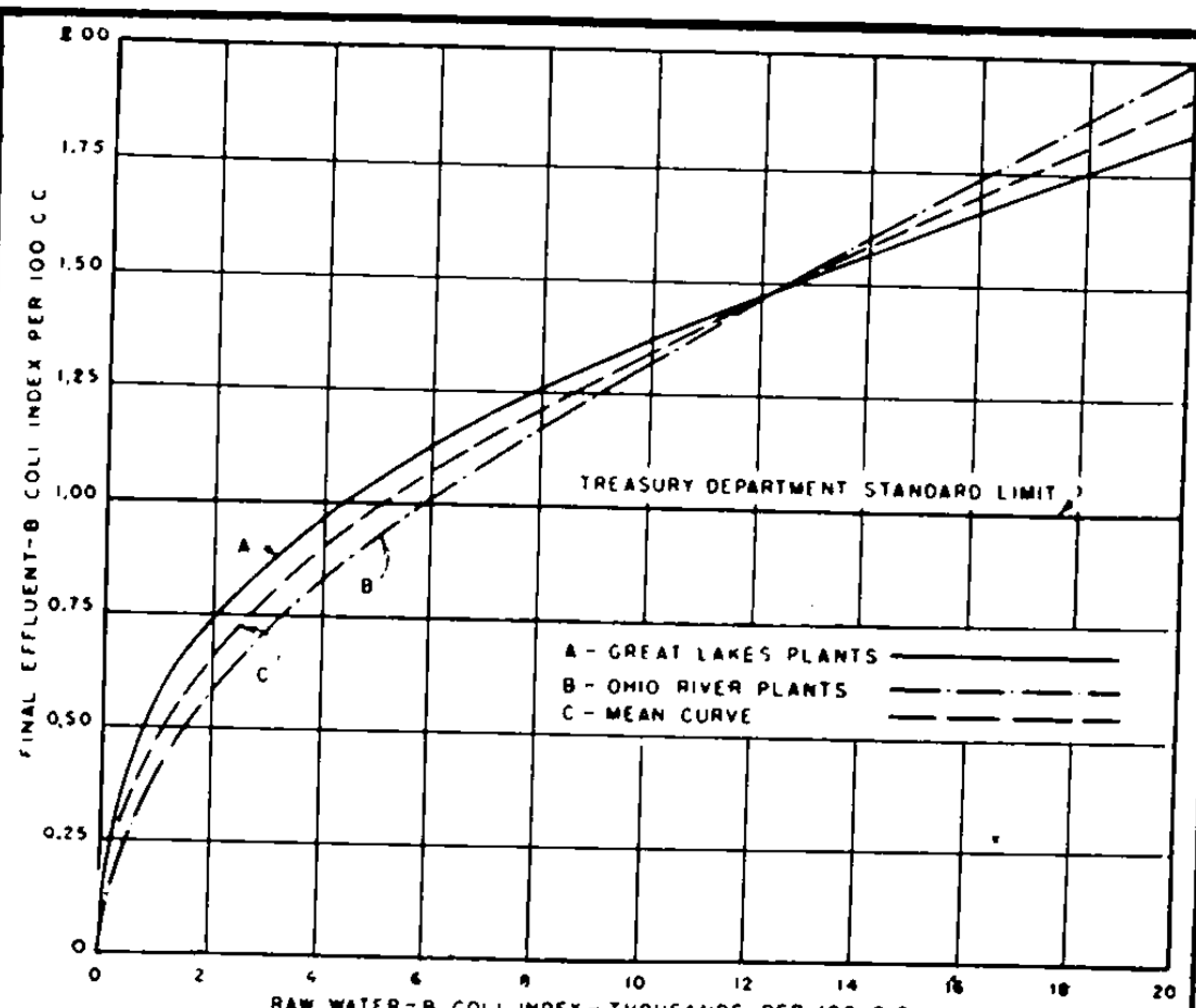
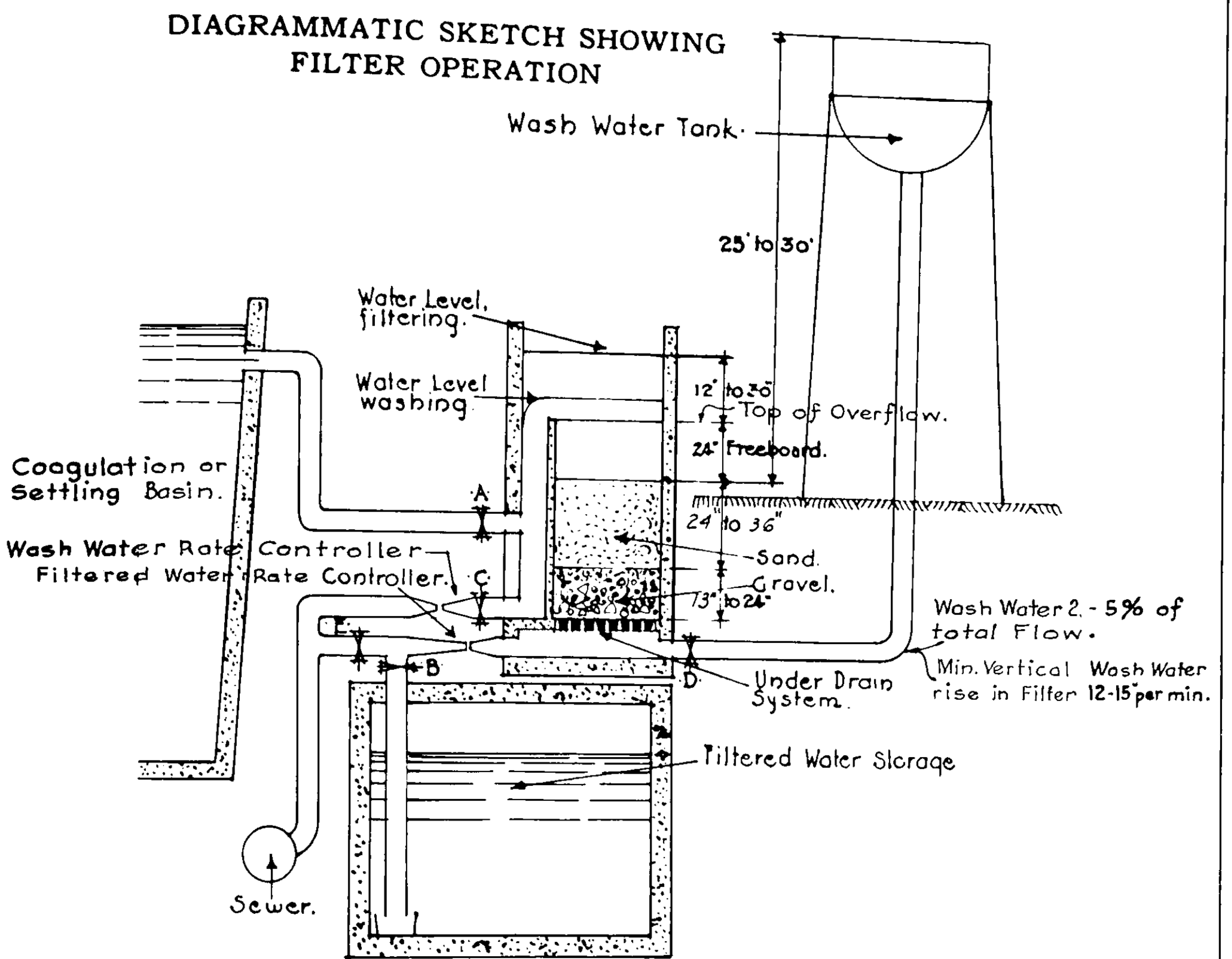


FIG. C-OBSERVED RELATIONSHIPS BETWEEN COLIFORM DENSITIES IN RAW WATERS AND THE FINAL EFFLUENTS PRODUCED BY RAPID FILTRATION.*

**Adopted from Manual of Water Quality & Treatment by Amer. Water Works Assoc. 1941.*

WATER PURIFICATION—RAPID SAND FILTER-2



How Filter Operates

1. Open valve A. (This allows water from settling basin to flow to filter.)
2. Open valve B. (This allows water to flow through filter to filtered water storage. During filter operation all other valves are closed.)

How Filter Is Washed

1. Close valve A.
2. Close valve B when water in filter filters down to top of overflow.
3. Open valves C and D. (This allows water from wash water tank to flow up through the gravel and sand, loosening up the sand and washing the accumulated dirt from the surface of the sand, out of the filter, and into the sewer.)

How to Filter to Waste

1. Open valves A and E. All other valves closed. Water is sometimes filtered to waste for a few minutes after filter has been washed in order to condition the filter before it is put into service.

Adapted from Water Supply & Treatment by C.P. Hoover. Published by National Lime Assoc. Wash., D.C.

WATER PURIFICATION—RAPID SAND FILTER-3

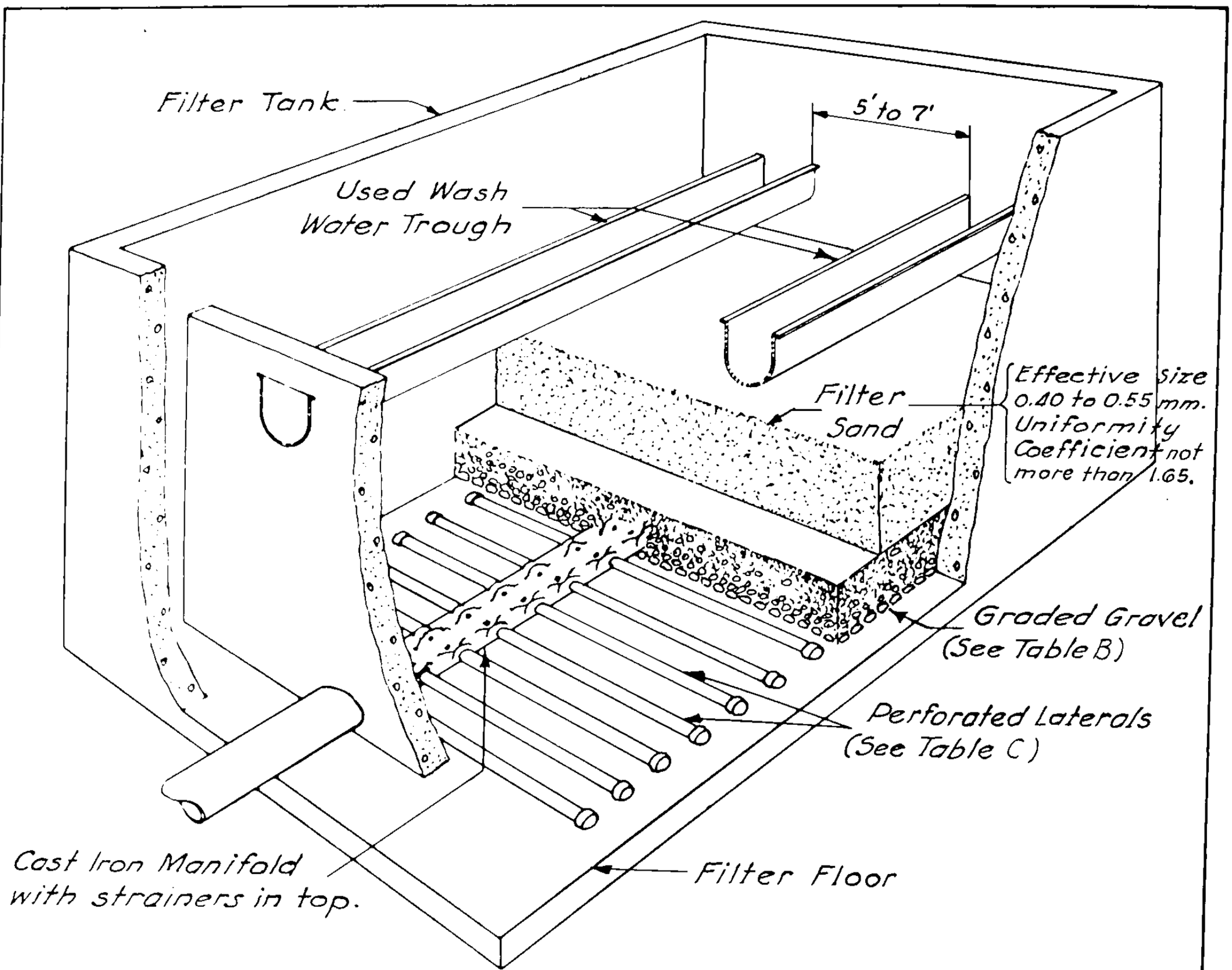


FIG. A - RAPID SAND FILTER SHOWING SAND LAYER, UNDERDRAINS, ETC.*

TABLE B GRADED GRAVEL**

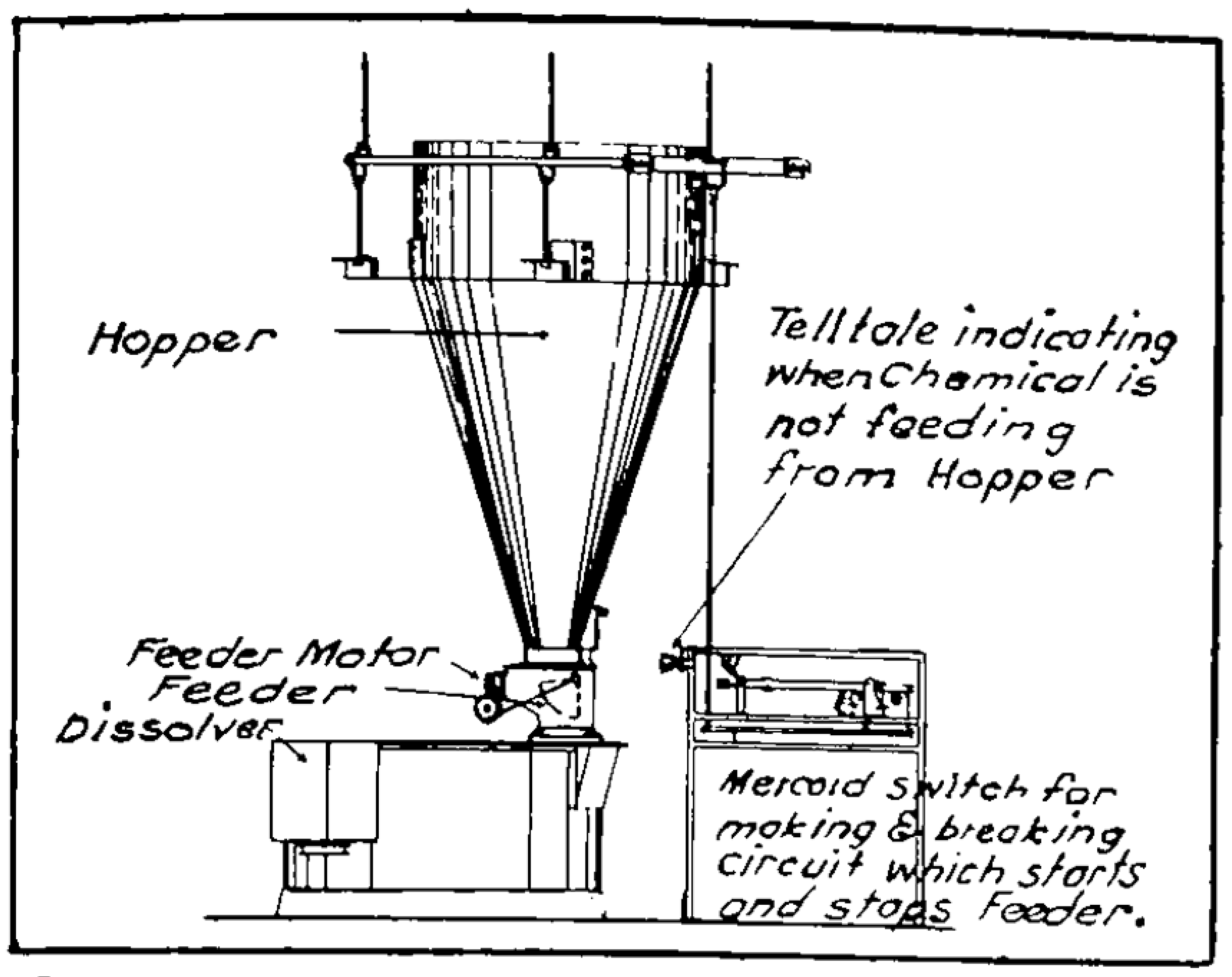
LAYER NO.	PASSING THRU SCREEN OPENINGS IN INCHES	RETAINED ON SCREEN OPENINGS IN INCHES	DEPTH OF LAYER IN INCHES
1 (Bottom)	2 1/2	1 1/2	2 to 4
2	1 1/2	3/4	3 to 6
3	3/4	1/2	2 to 4
4	1/2	1/4	2 to 4
5	1/4	1/8	2 to 4
6 (Top)	(Torpedo) Sand 1.2 to 0.8 mm.		2

TABLE C - UNDERDRAINS***

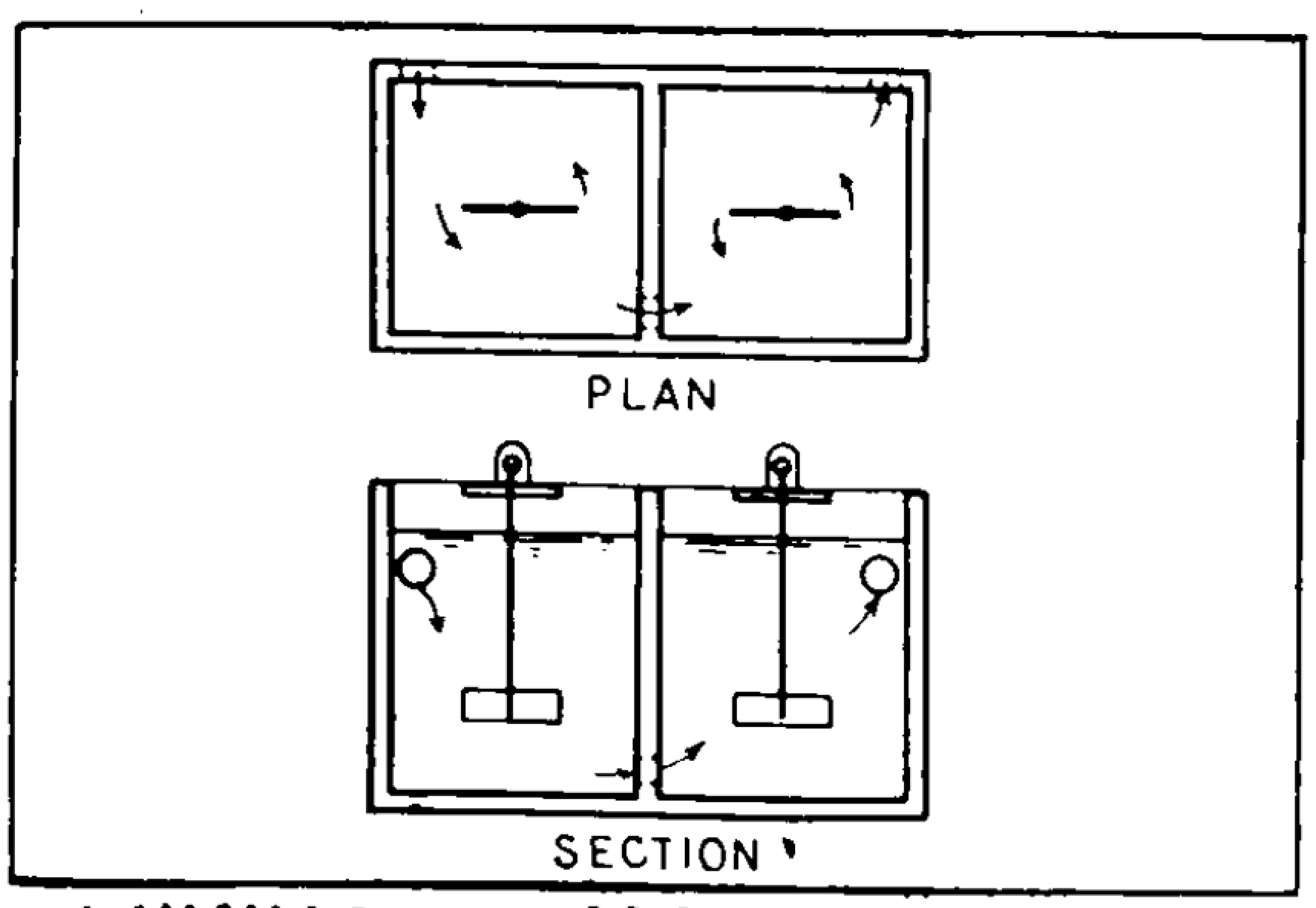
Diameter of perforations.	1/4"	1/2"
Spacing of perforations along laterals.	3"	8"
Max. ratio of total area of perforations to total cross-sectional area of laterals.	0.25	0.5
Minimum total area of perforations per square foot of filter.	0.3 Sq. In.	0.3 Sq. In.
Maximum spacing of laterals.	12"	12"
Max. ratio of length of lateral to its Diam.	60	60
Rate of washing in Cu. ft. per Sq. ft. of filter per min.	0.5-3.0	0.5-3.0

*Adapted from Manual of Water Quality and Treatment by American Water Works Association.
**From Water Supply and Treatment by C.P. Hoover. Published by National Lime Assoc. Wash., D.C.
***Adapted from An Investigation of Perforated-Pipe Filter Underdrains by H.N. Jenks-Eng. News Record.

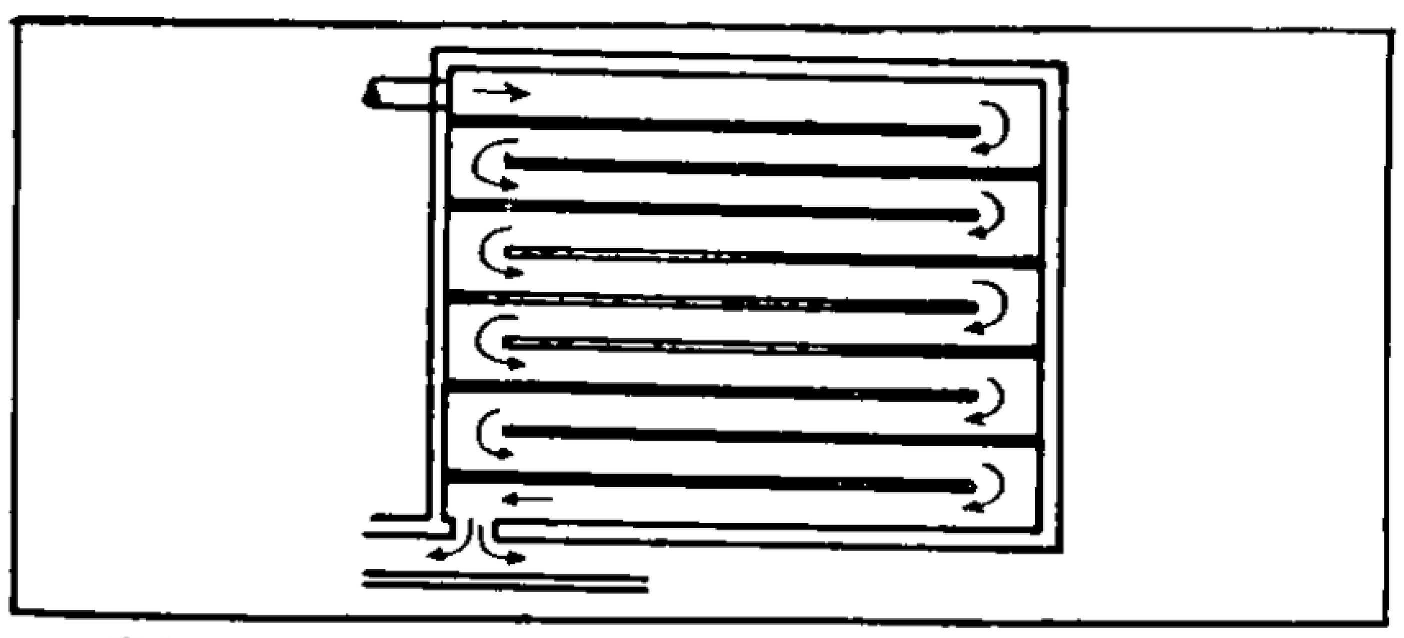
WATER PURIFICATION-RAPID SAND FILTRATION EQUIPMENT



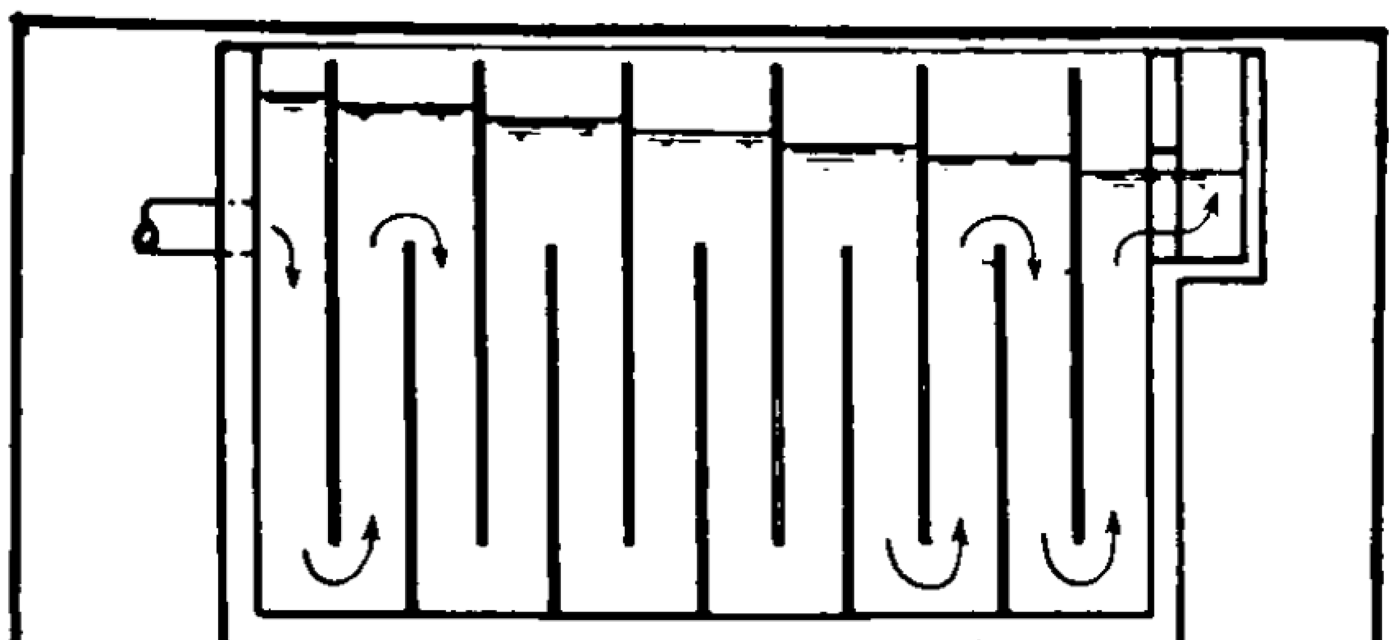
CHEMICAL FEEDING DEVICE FOR CONTINUOUSLY WEIGHING & DISSOLVING CHEMICALS.*



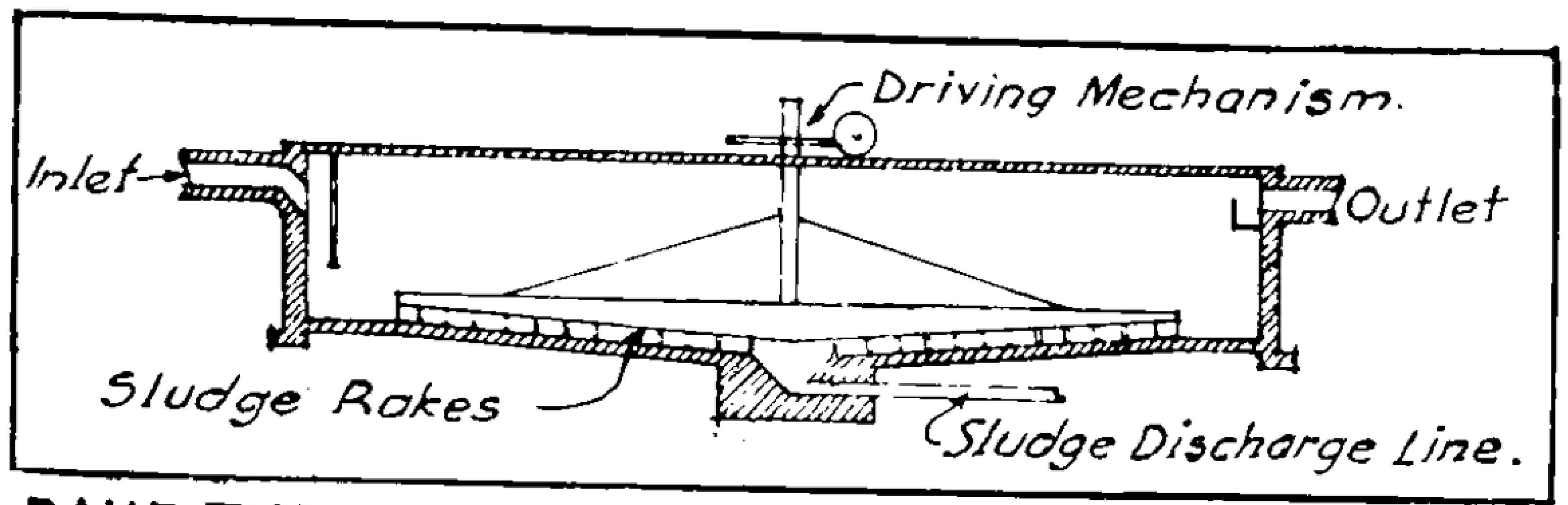
MIXING CHAMBER WITH MECHANICAL AGITATION.**



PLAN OF ROUND-THE-END BAFFLED MIXING BASIN.**

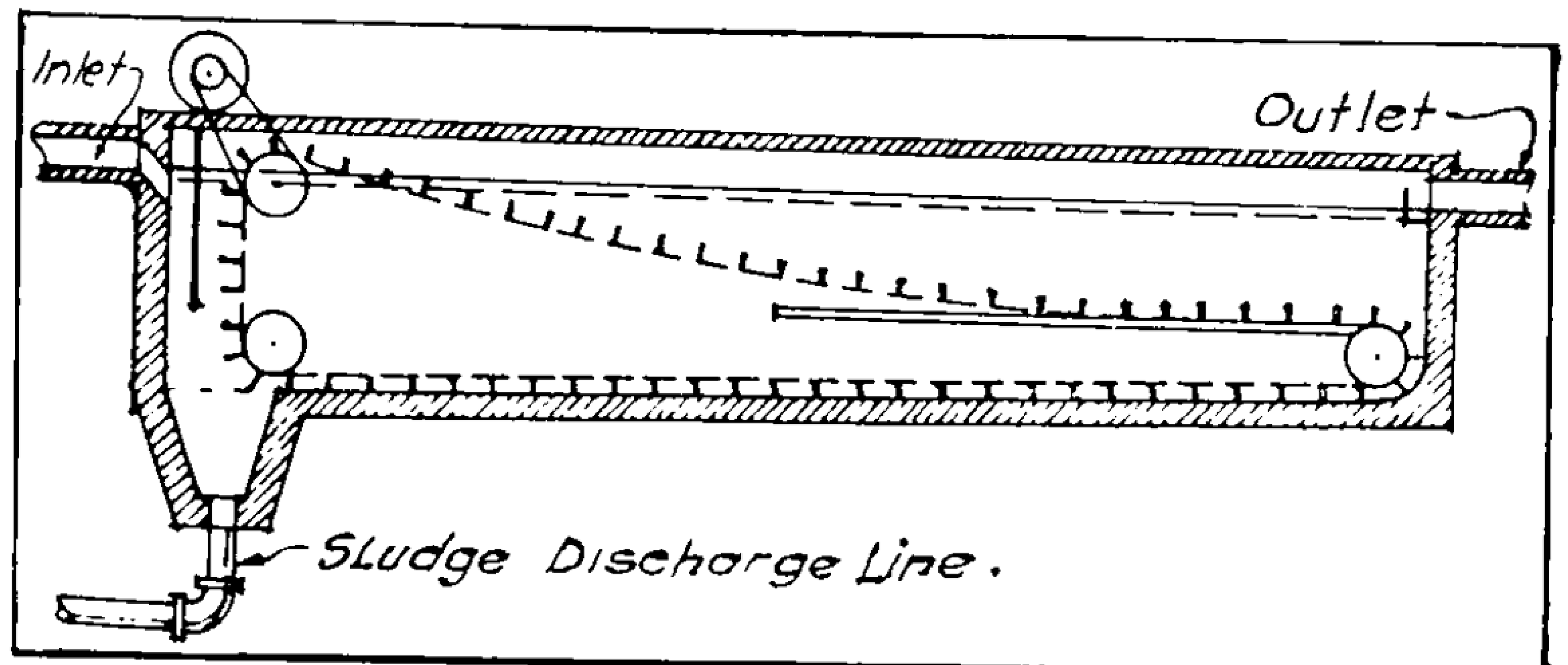


SECTION THROUGH OVER & UNDER BAFFLED MIXING CHAMBER.**



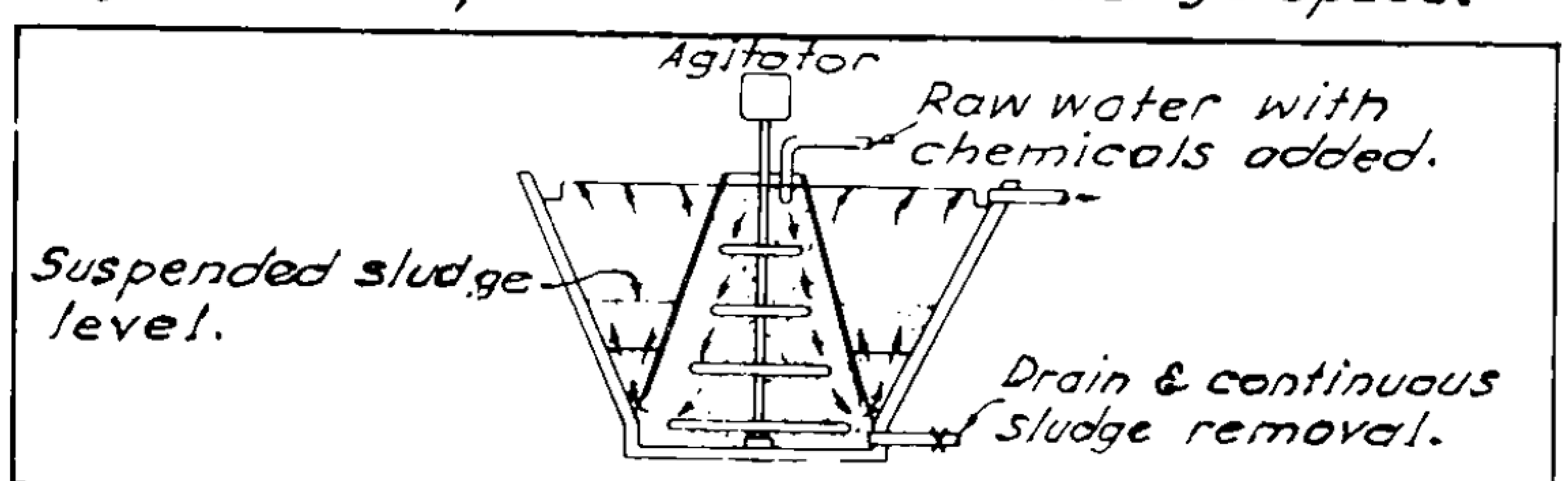
RAKE TYPE CONTINUOUS SLUDGE REMOVING DEVICE.*

[Used on circular and square settling tanks. (Coagulation basin)].

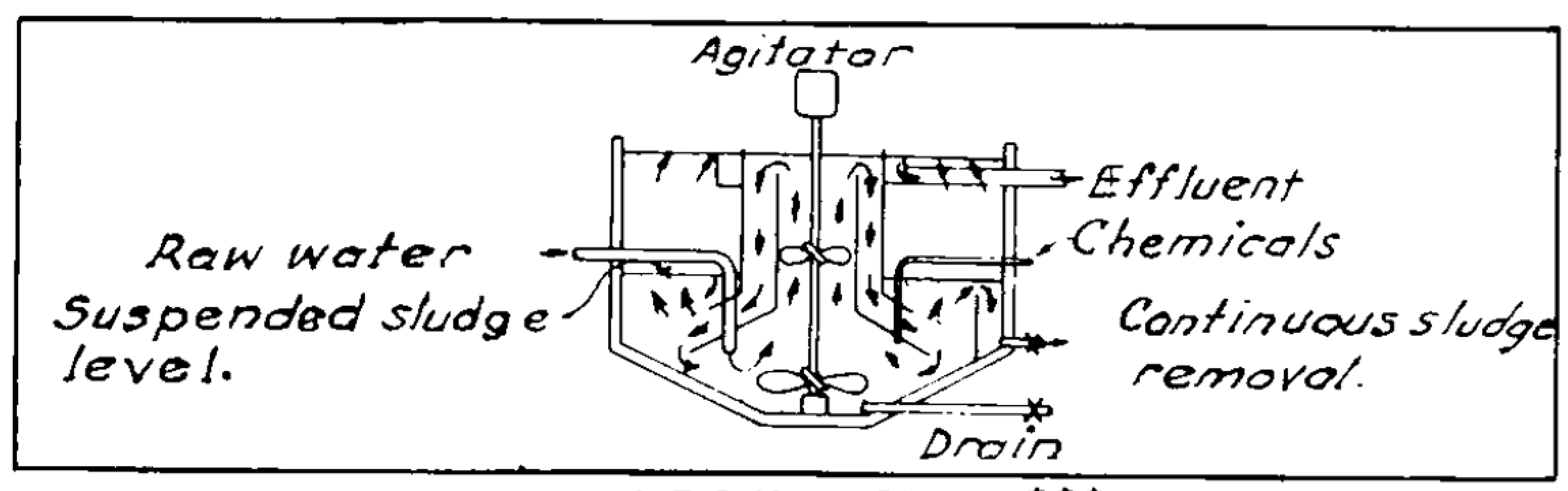


SCRAPER TYPE CONTINUOUS SLUDGE REMOVAL DEVICE.*

For rectangular settling tank (coagulation tank).
NOTE: If sludge is not removed mechanically use larger tank to provide sufficient storage space.

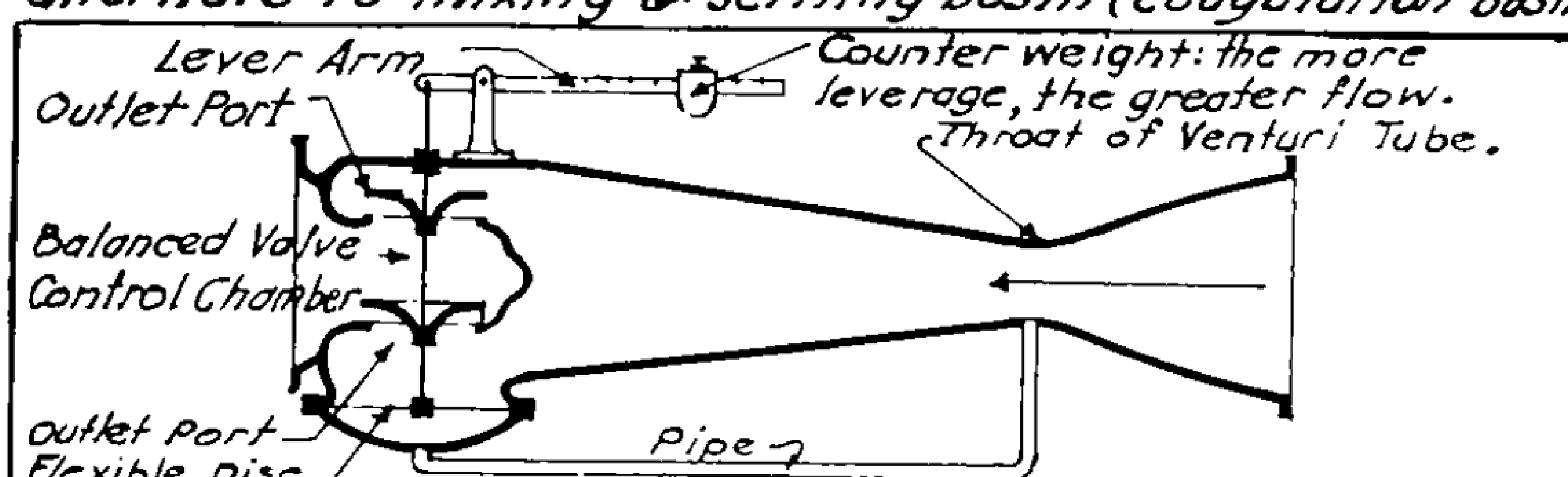


PRECIPITATOR***



ACCELATOR***

NOTE: Precipitator or Accelator is used as an alternate to mixing & settling basin (coagulation basin).



RATE OF FLOW CONTROLLER*

May be operated by Hydraulic Cylinder & Pilot Valve instead of Lever Arm.

* From Water Supply and Treatment, by C.P. Hoover. Published by National Lime Assoc. Wash., D.C.
** From Davis, Handbook of Applied Hydraulics, McGraw-Hill.
*** From Manual of Water Quality & Treatment by American Water Works Assoc. 1941.

WATER PURIFICATION-PRESSURE FILTERS

NOTE: Models are also made with one valve substituting for all valves shown. Sometimes raw water inlet is used also as wash water inlet. Then rate of flow controller is placed in filtered water outlet line.

NOTE: Pressure filters are generally used when raw water is supplied under pressure thus removing the necessity of repumping the effluent to the point of service.

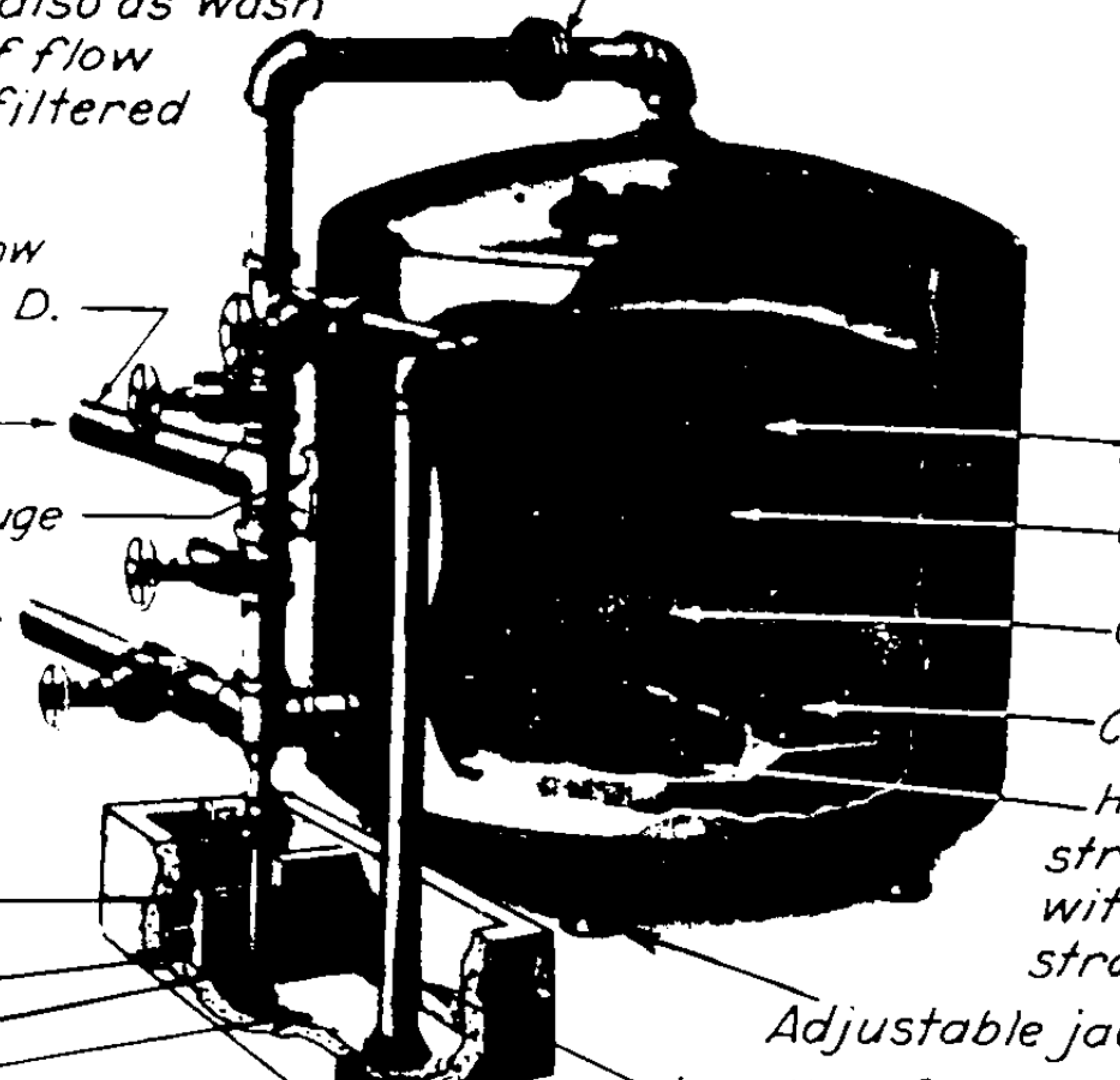


FIG. A - VERTICAL PRESSURE FILTER - TYPE "E" (PERMUTIT CO.)*

NOTES: Dimensions and capacities differ slightly with different models.

Horizontal pressure filters are also manufactured. Their approximate capacities range from 134-516 g.p.m.

TABLE B - CAPACITY AND DIMENSIONS OF TYPE "E" VERTICAL FILTERS.*

Diam.	Height Overall	Minimum Head Room	Floor Space Operating	Size of Pipe	Capacity G.P.M. 2-gal. Rate	Capacity G.P.M. 3-gal. Rate	Back Wash G.P.M.
30"	6' 11"	7' 10"	3' 0" x 5' 9"	2"	9.8	14.7	49
36"	7' 1"	8' 1"	3' 6" x 6' 3"	2"	14.2	21	71
42"	7' 1"	7' 4"	4' 0" x 6' 9"	2"	19	29	96
48"	7' 3"	7' 7"	4' 6" x 7' 7"	2½"	25	38	126
54"	7' 4"	7' 8"	5' 0" x 8' 1"	2½"	32	48	159
60"	7' 5"	7' 9"	5' 6" x 8' 7"	3"	39	59	196
66"	7' 8"	8' 1"	6' 0" x 9' 3"	3"	48	72	237
72"	7' 8"	8' 4"	6' 6" x 9' 9"	3"	57	85	283
78"	7' 9"	8' 7"	7' 0" x 10' 3"	4"	67	100	332
84"	8' 2"	9' 0"	7' 6" x 11' 5"	4"	77	115	385
90"	8' 3"	9' 3"	8' 0" x 12' 0"	4"	88	132	440
96"	8' 4"	9' 10"	8' 6" x 12' 6"	4"	100	150	500
108"	8' 9"	10' 0"	9' 6" x 13' 9"	5"	127	191	630
120"	9' 0"	10' 10"	10' 6" x 14' 9"	5"	157	236	780

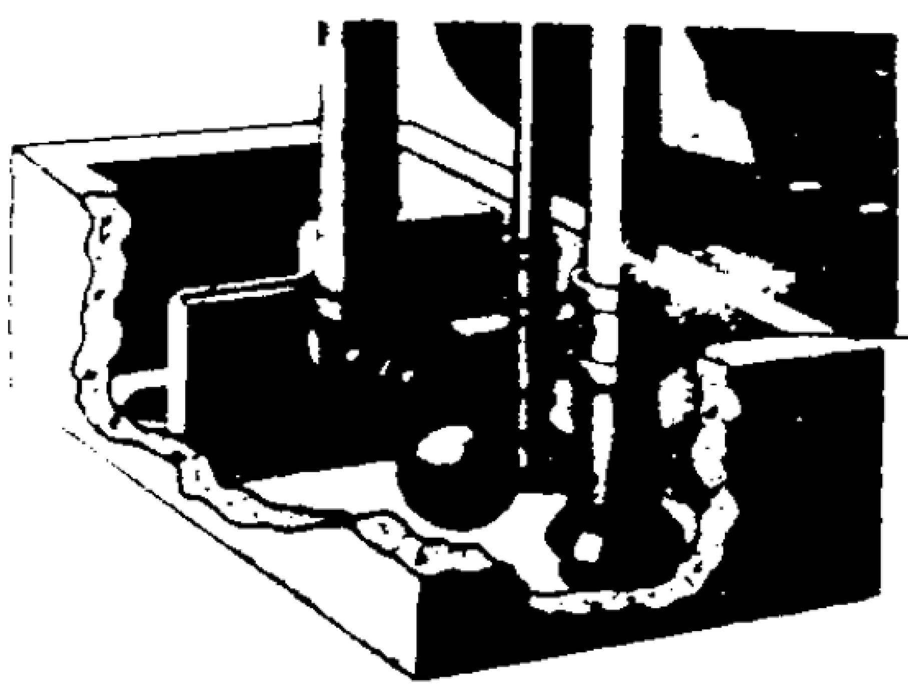


FIG. C - WASH RATE OF FLOW CONTROLLER.*

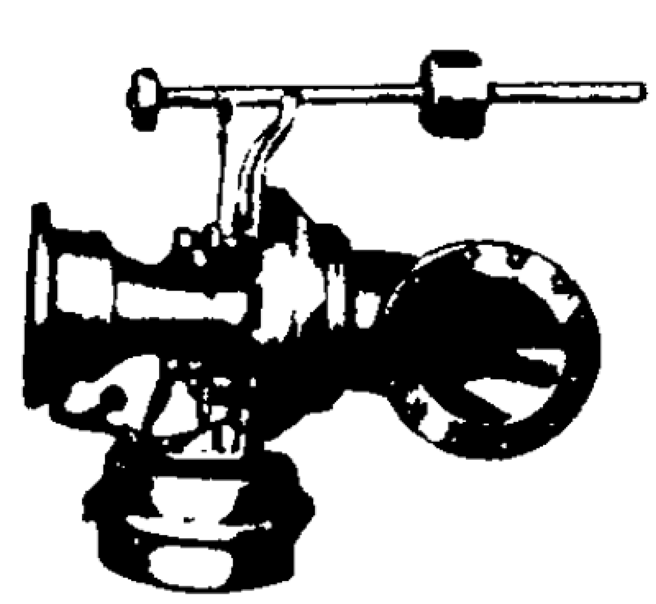


FIG. D - RATE OF FLOW CONTROLLER.*

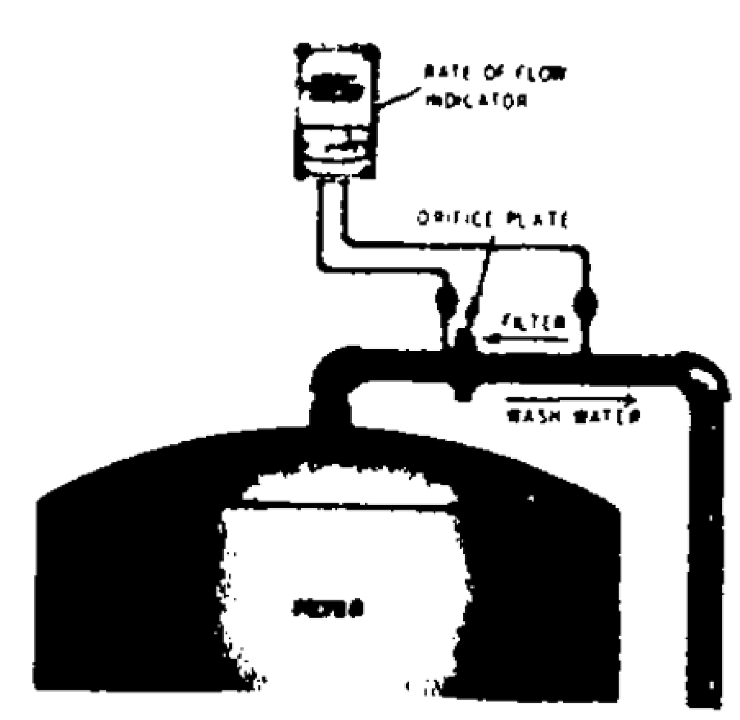


FIG. E - RATE OF FLOW INDICATOR.*

* From Permutit Co. Bulletin No. 2225.

WATER PURIFICATION - LABORATORY EQUIPMENT*-1

LABORATORY FURNITURE, APPARATUS, AND SUPPLIES FOR WATER FILTRATION PLANTS

1. GENERAL - The following schedule of laboratory furniture, apparatus, and supplies has been prepared for the various types of water filtration plants, as follows:

   a. Class A Plants - Filtration plants serving a population of more than 10,000 or treating surface water taken from a polluted source where complete control is required for the operation of the plant. The laboratory equipment provided will permit routine chemical and bacteriological analyses, as well as microscopic examinations.

   b. Class B Plants - Filtration plants taking water from a slightly polluted source or from wells where softening or iron removal is required. The laboratory equipment provided will permit routine chemical control tests, bacteriological tests for coliform organisms, and total plate counts.

   c. Class C Plants - Plants where chlorination only is provided to insure the bacteriological quality of the supply. The laboratory equipment will permit routine residual chlorine, pH, and alkalinity determinations only. The list of laboratory furniture and apparatus is considered to be the minimum required. The equipment listed is complete in itself with all necessary details and accessories.

2. LABORATORY FURNITURE - The following list of laboratory furniture includes those items required in Class A and B plants. It is the intention that this equipment will meet the minimum requirements for laboratory furniture. However, discretion should be exercised in selecting furniture that will fit the space requirements in the laboratory and harmonize with other facilities. It is recommended that the several units be purchased ready-made, as this type is preferable to built-in furniture. The equipment listed is complete in itself with all necessary details and accessories and the items listed are standard with at least three manufacturers. The tops of the table and the benches are of specially treated materials to resist the action of the chemicals. The furniture required is as follows:

   Item 1. One (1) laboratory table of oak, approximately 6'-0" long, 32" wide and 36" high. Table shall be fitted with a maple bottle rack with acid resisting back; rack shall be approximately 60" x 8" x 18". Peg board over sink, 14" x 19½", shall be fitted with 16 pegs. Table top shall be fitted with a lead lined (4 lbs. per sq. ft.) trough, approximately 66" x 4" x 6"/3". All joints shall be burned with pure lead; soldering not permitted. Sink with back at end of table 14" x 18" x 12" mounted on tubular stand shall be of 1¼" selected soapstone. Sink shall have 2" lead "P"

* From Engineering Manual, War Dept., Corps of Engrs., March 1942.

WATER PURIFICATION - LABORATORY EQUIPMENT *-2

trap; for connection see plumbing. Cabinet supporting frame shall be mortised and tenoned, glued and reinforced with bolts. Drawers shall be dovetailed, doors shall be built up and shall have suitable pulls, catches, and hinges. The cabinet shall be equipped with two long drawers at top, four intermediate drawers, and two cupboards. Cupboards shall be fitted with two adjustable removable shelves. Top shall be of Shellstone or approved acid resisting material. Equipment shall have two compression hose bibs over sink for hot and cold water; three straight-way water cocks with hose connection over trough; and $\frac{1}{2}$" pipe conduit with two duplex receptacles with "T" slots, mounted in cast metal conduit fittings. Connections shall be made to floor outlets. All service lines shall be carried to floor with shut-off for each line. Finish for all exposed steel and service piping shall be acid and alkali resisting enamel. Table shall be type #16560 as manufactured by E. H. Sheldon & Co., Muskegon, Mich. or a similar table as manufactured by W. W. Kimball Co., Chicago, Ill., or Hamilton Mfg. Co., Two Rivers, Wis.

Item 2. One (1) balance shelf, 3' long x 2' wide; oak construction, except for 1 5/8" thick birch, black carbonized top; equipped with drawer 21" wide, 15" deep, 3 3/4" high. Shelf to be equivalent to

E. H. Sheldon & Co.	No. 12520
W. W. Kimball Co.	No. 682
Hamilton Mfg. Co.	No. L-1174

Item 3. One (1) supply case, 48" wide, 15" deep, 80" high, upper section glazed 44" wide, 60" high with 3 adjustable shelves; cupboard shelves; cupboard section 44" wide, 12" deep, 13" high, of oak.

E. H. Sheldon & Co.	No. 41040
W. W. Kimball Co.	No. 9562
Hamilton Mfg. Co.	

Item 4. One (1) lower section cupboard unit, 37 5/8" long x 24" wide x 36" high containing 1 double cupboard 34" wide x 28$\frac{1}{4}$" high x 20 5/8" deep, with 1 stone sink 14 1/4" long x 10" wide x 8" deep with 1 set of drain fittings, 1 cold water pantry cock and 1 double electric receptacle for 110-V A.C., table top to be scored to drain to sink.

E. H. Sneldon & Co.	
W. W. Kimball Co.	
Hamilton Mfg. Co.	No. L-804

All furniture shall be of oak construction, natural finish throughout except table tops, which are to be 1 5/8" birch black carbonized.

* From Engineering Manual, War Dept., Corps of Engrs., March 1942.

WATER PURIFICATION - LABORATORY EQUIPMENT *- 3

Item 5. In laboratories for Class C plants, the furniture to be provided shall consist of a work table at least 48" long x 36" wide and 30" high, together with a wall cabinet fitted with doors. The cabinet shall be of adequate size to house equipment and chemicals required for a Class C laboratory. These items need not be of special laboratory construction, as kitchen type or built-in-place furniture will suffice. A laboratory sink should be provided convenient to the work table.

3. LABORATORY APPARATUS - The following list of laboratory apparatus includes those items required in Class A, B, and C plants:

QUANTITY			DESCRIPTION	CATALOGUE NUMBERS		
Type of Plant				Central Scientific Co.	E. H. Sargent Co.	Chicago Apparatus Co.
A	B	C				
1	1		Balance, analytical, student model, chain type	1020	S--2675	40200
1	1		Balance cover, rubberized cloth, for above	2020	S--3965	42710
1	1		Set balance weights, Class S, 100 mg. to 100 gm.	8170-B	S--4075	42100-B
1	1	1	Harvard trip scale balance	3470	S--3215	40430
1	1	1	Set balance weights 1 to 500 grams	9140	S--4285	42480-E
1	1		37°C electric incubator, 14" x 12" x 11-3/4"	46010		
1	1		Small refrigerator			
1	1	1	Two-burner hot plate	16685	S--41475	74550-B
1	1		Two-burner gas oven			
1	1		Pressure sterilizer, 11" x 24"	44120-A	S--76025A	79470-A
1			Electric muffle furnace, Hoskins Type FD	13675-A	S--36855A	71875-A
1	1		Jackson turbidimeter	29105	S--83705	81000
1	1		Water still - capacity 1 gal. per hour	12760-A	S--27465	66330-A
12	12	6	Wide-mouth bottles, glass stoppered, 30-32 oz.	10450		45640
18	18		Wide-mouth bottles, glass stoppered, 125 ml.	10450		45640
6			Dropping bottles, 30 ml.	10580	S--8785	48100
6	6	3	Dropping bottles, 60 ml.	10580	S--8785	48100
2	2	2	Wash bottles, 1000 ml.	10710	S--9365	
2	2		Pyrex bottles for distilled water, 2½ gal.	10480		
4	2	2	Cylinders, double graduated, 100 ml.	16125	S--24695	64860
2	1		" " " 500 ml.	16125	S--24695	64860
2	1		" " " 1000 ml.	16125	S--24695	64860
1	1		Volumetric flasks, vial mouth 50 ml.	16225	S--34845	70900
2	1		" " " " 100 ml.	16225	S--34845	70900

* From Engineering Manual, War Dept., Corps of Engrs., March 1942.

WATER PURIFICATION - LABORATORY EQUIPMENT*-4

QUANTITY Type of Plant A	B	C	DESCRIPTION	CATALOGUE NUMBERS Central Scientific Co.	E. H. Sargent Co.	Chicago Apparatus Co.
1	1	1	Thermometer, Centigrade, -5° to 205°	19225-B		
1	1		Watch glasses, counterpoised, (pair)	2250-A	S-3785	45650-A
2	2	2	Absorption tube, to hold soda lime	14755-A	S--28815	73460-A
1			Desiccator, 250 mm.	14550	S--25015	65030
6	4	2	Evaporating dishes, porcelain, 75mm.	18575	S--25505	65210
4	2		Evaporating dishes, porcelain, 90 mm.	18575	S--25505	65210
1	1		Pipette stand	19120	S--78905	78110
1	1		Burette support	19080	S--78355	79110
1	1	1	Burette clamp, steel	12115		49710
1	1		Gas burner, Meeker or Fisher	11105	S--12195	50560
2	1		" " " " 250 ml.	16225	S--34845	70900
2			" " " " 500 ml.	16225	S--34845	70900
1	1		" " " " 1000 ml.	16225	S--34845	70900
24	24	6	Erlenmeyer flasks, Pyrex, 250 ml.	14905	S--34105	70750
6	6	4	" " " 500 ml.	14905	S--34105	70750
2	2		" " " 1000 ml.	14905	S--34105	70750
4	2		Beakers, Pyrex, 50 ml.	14265	S--4675	44300
4	2		" " 150 ml.	14265	S--4675	44300
12	6	4	" " 250 ml.	14265	S--4675	44300
4	2		" " 400 ml.	14265	S--4675	44300
6	2		" " 600 ml.	14265	S--4675	44300
12	4	2	Beaker covers, $3\frac{1}{2}$ in.	15850	S--83605	80890-E
1			Filtering flask, 500 ml.	14985	S--34375	70840
2			Filtering crucibles, Alundum, RA360, 25 ml.	10065-A	S--24375	
2			Rubber crucible holder	18110	S--24475	64480
2	2		Funnels, 100 mm. diam.	15070	S--35305	71260
4	2		" 65 mm. diam.	15070	S--35305	71260
2	2	2	" long stem, 100 mm. diam.	15050	S--35315	71200
12	12		Nessler tubes, 100 ml., marked at 50 ml.	29060-C	S--21035	62130
4	4	2	Burettes, graduated in 0.1 ml., 50 ml.	15925-C	S--10635	49320-A
2	2		Burettes, " " " " 25 ml.	15925-B	S--10635	49320-B
4	4	1	Pipettes, volumetric, Exax blue line, 1 ml.	16335	S--69515	78010
4	4		Pipettes, volumetric, Exax blue line, 5 ml.	16335	S--69515	78010
4	4		Pipettes, volumetric, Exax blue line, 10 ml.	16335	S--69515	78010
3	2	1	Pipettes, volumetric, Exax blue line, 25 ml.	16335	S--69515	78010
3	2	1	Pipettes, volumetric, Exax blue line, 50 ml.	16335	S--69515	78010

* From Engineering Manual, War Dept., Corps of Engrs., March 1942.

WATER PURIFICATION - LABORATORY EQUIPMENT *-5

QUANTITY Type of Plant A	B	C	DESCRIPTION	CATALOGUE NUMBERS Central Scientific Co.	E. H. Sargent Co.	Chicago Apparatus Co.
2	2	1	Gas burner, Bunsen, Tirrill Type	11025	S--12295	50270
2	2	1	Stone jars for waste, 2 gal.	16925-B	S--43945	75780-B
4	2		Pinchcocks, Mohr, 2½ in.	12186	S--19495	56740-B
2	2	1	Clamps, test tube	12155	S--19555	56680
1			Spoon, horn	18775-C	S--75175	79225-B
1	1		Spatula, stainless steel	18755-B	S--75245	79220-D
1			Filter pump aspirator		S--33575-A	70160
2	1	1	File, triangular, 6"	88325	S--32235	69630
1	1	1	Funnel support, hardwood	19035	S--78815	71670
1	1	1	Iron ring stand; 3 rings,3",4",5"	19072-B	S--78365	79905
1	1		Nessler tube stand	29070-B	S--21075	62140-C
2	2	1	Wire gauze, 4"	19970-A	S--85325	81050
2	2	1	Triangles, 2½"	19375-C	S--82415-C	80540
2	2		Tripod with concentric rings	19775-B	S--82515-B	80565-B
2	2	1	Tongs, 9"	19600	S--82115	8490-B
2	1		Camel's hair brush, medium	10938-A	S--9725	
2	2	2	Brushes, flask	10985-B	S--9965	49180
2	2	2	" tube	10970	S--9985	49250-A
2	2	2	" "	10974	S--1005	
12			Vacuum tubing, 1/4" bore (feet)	18204-C	S--73525	78880-C
24	24	12	Rubber tubing, " " "	18202-C	S--73515	78805-C
12	12	6	" " 1/8" bore (feet)	18250-A	S--73565	78850-A
1	1	1	Corks, bags of assorted sizes,3 to 16	12404	S--23075	63805-B
1	1	1	Cork borer, size 4 to 11 mm. (set)	12460-B	S--23175	63880-B
1	1	1	Rubber stoppers, assorted (lbs.)	18153-A	S--73305	78785-A
4	4	2	Filter paper, 9 cm. (boxes)	13250	S--32915	69710
2	2	1	" " 12.5 cm. (boxes)	13250	S--32915	69710
1	1		" " quantitative, 9 cm.(box)	13355	S--32785	69920
12	6	2	Glass marking pencils	14015-C	S--65765	77965
			HYDROGEN ION COMPARATORS			
1	1		Hellige comparator, #600, standard model, 620/39	21430		
1	1		Additional discs, pH, 620/48			
1	1		" " chlorine, 620 C-7			
		1	Hellige Simplex comparator, #603, 622/39	21400-J		
		1	Additional color plate,pH,622/48			
		1	" " " chlorine, 622 C-7A			
**1a	1a	1a	LaMotte block comparator, pH, Range 6.0-7.6,bromthymol blue	21500-H	S--41725-H	
**1a	1a	1a	LaMotte block comparator, pH, range 7.2-8.8, cresol red	21500-K	S--41725-K	
**1a	1a	1a	LaMotte block comparator, chlorine			
**1b	1b	1b	LaMotte Universal pH outfit, model 33			

* From Engineering Manual, War Dept., Corps of Engrs., March 1942.

**1a and 1b are alternate items.

WATER PURIFICATION - LABORATORY EQUIPMENT *-G

QUANTITY Type of Plant A	B	C	DESCRIPTION	CATALOGUE NUMBERS Central Scientific Co.	E. H. Sargent Co.	Chicago Apparatus Co.
			BACTERIOLOGICAL			
1			Microscope, monocular, Bausch & Lomb, No. H 8	61050	S--52085	76264-C
24	24		Pipettes, 1.1 ml. capacity, graduated at 1.0 ml.	46650-B		78020-B
24	24		Pipettes, 11 ml. capacity, graduated at 10 ml.	46650-F		78020-F
30	30		Culture dishes with covers, 100 mm. x 15 mm.	44370-D	S--25925-B	65270-A
1	1		Culture tubes, large, 7" x 7/8" (gross)	44500	S--79525	80610
1	1		Vials for large culture tubes (gross)	44500	S--79525	80610
1	1		Culture tubes, small, 6" x 3/4" (gross)	44500	S--79525	80610
1	1		Vials for small culture tubes (gross)	44500	S--79525	80610
1	1		Thermometer, Centigrade, 0° to 110°	19255-A	S--80305	
1			Glass slides, 37 mm. x 75mm. (gross)	66310	S--58785	76805
1			Cover slips (gross)	66510	S--58715	76810
1			Lens, reading glass	60400		
1	1		Counter, tallying machine	73320	S--23285	64070
1	1		Counting apparatus	44320	S--23395	64000
2	2		Culture dish holder	44400	S--26055	65320-B
2	2		Pipette sterilizing boxes, copper, $2\frac{1}{2}$" x 16"	46670-B	S--69815	78090
2	2		Test tube support	19200-A	S--79005	80790
4	4		Test tube basket	48520-B	S--79835	80755-E
1	1		Double boiler, 2 qts.	12970	S--8215	
1			Inoculating needle holder	46220		77535
1			Forceps (Chromel)	66600		76970
1			Inoculating needles (24 B&S Gauge) (Package)	46210	S--62755	77540
1			Lens paper (quire)	12290	S--44325	76865
			MICROSCOPICAL			
1			Sedgewick rafter filter	29032	S--84005	80960-B
24			Cloth discs to support filter sand	29034	S--84025	80965-B
1			Counting cell	29035	S--84045	80940
12			Cover cells	29036	S--84055	80940-A
1			Eyepiece micrometer	29037	S--84065	80950
1	1	1	Book, Standard Methods of Water Analysis			

* From Engineering Manual, War Dept., Corps of Engrs., March 1942.

WATER PURIFICATION - LABORATORY EQUIPMENT †-7

STANDARD SOLUTION FOR WATER ANALYSIS ACCORDING TO AMERICAN PUBLIC HEALTH ASSOCIATION STANDARD METHODS OF WATER ANALYSIS, EIGHTH EDITION, 1936

Platinum-cobalt standard, color 500	200 ml.
Standard calcium chloride solution	500 ml.
Standard soap solution	1000 ml.
Standard ferric iron solution	500 ml.
Standard silver nitrate	500 ml.
Soda reagent	1000 ml.
Acid, sulphuric, N/50 solution	1000 ml.
Sodium hydroxide, N/50 solution	500 ml.
Sodium hydroxide, N/44 solution	500 ml.
Potassium thiocyanate	500 ml.
Acid, hydrochloric, dilute approximately 3 N	500 ml.
Potassium permanganate, approximately N/5	500 ml.
Acid nitric, 6 N Solution	500 ml.
Methyl orange indicator	500 ml.
Phenolphthalein indicator	500 ml.
Erythrosine indicator	500 ml.
Potassium chromate indicator	100 ml.

CULTURE MEDIA
FORMULAS OF "STANDARD METHODS OF WATER ANALYSIS"

Bacto-nutrient agar, dehydrated	1 lb.
Bacto-lactose broth, dehydrated	1 lb.
Levine's-Eosin methylene blue agar. Difco	$\frac{1}{4}$ lb.

BACTERIOLOGICAL STAINING SOLUTIONS
ACCORDING TO "STANDARD METHODS OF WATER ANALYSIS"

Bismark brown	$\frac{1}{4}$ lb.
Carbol fuchsin	$\frac{1}{4}$ lb.
Carbol gentian violet	$\frac{1}{4}$ lb.
Gram's iodine stain	$\frac{1}{4}$ lb.
Methylene blue, Koch's	$\frac{1}{4}$ lb.
Safranin stain	$\frac{1}{4}$ lb.
Potassium iodide	$\frac{1}{2}$ lb.

NOTE: For Class A plants chemicals should be bought in bulk and standard solutions and reagents prepared by the plant chemist. This may apply in part to Class B plants.

†From Engineering Manual, War Dept., Corps of Engrs.. March 1942.

WATER DISTRIBUTION-PIPE SYSTEM, FLOW DATA

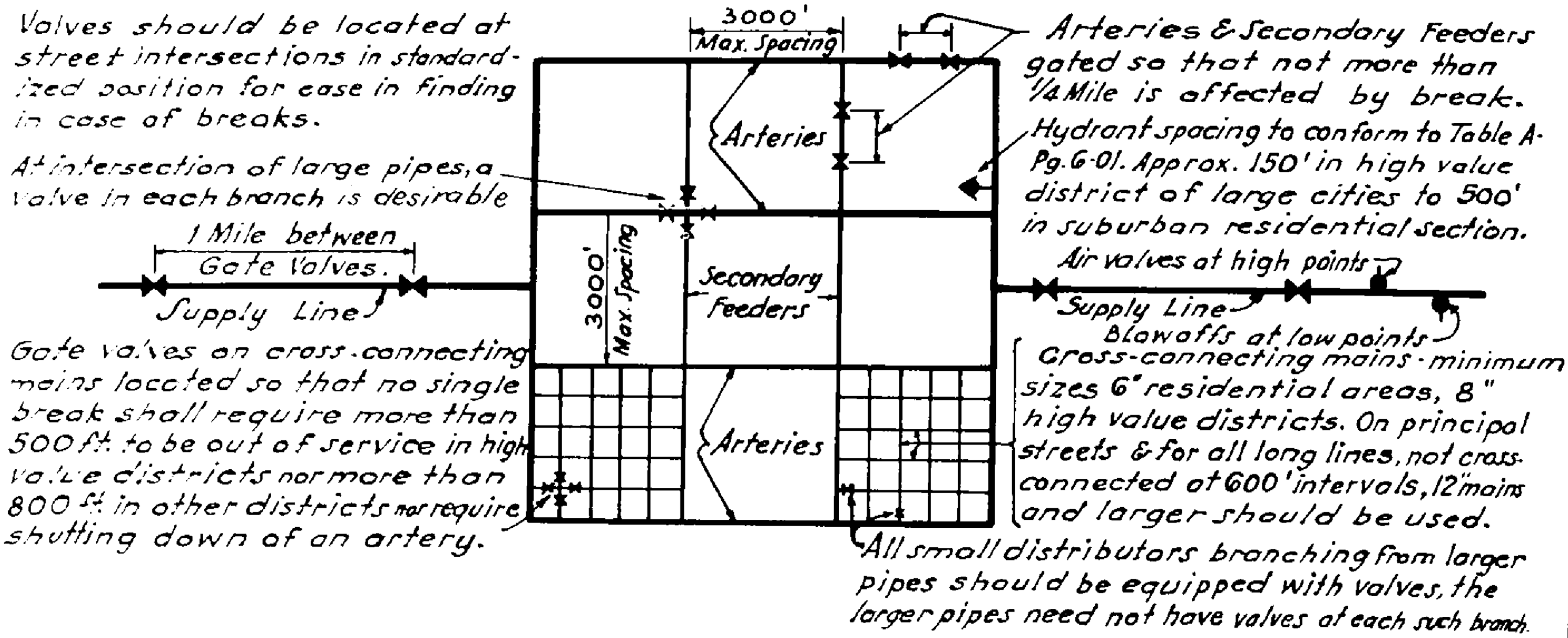


FIG. A - GENERAL ARRANGEMENT OF PIPE SYSTEM.

FIRE FLOW IN PIPES - PRACTICAL APPLICATIONS.

Design of new systems - select total fire flow from Table A, Pg. 6-01. Assume this flow at two or more hydrants at 750 g.p.m. per hydrant in an otherwise closed system. (Allow for domestic use if large.) Compute residual heads by Equivalent Pipe or Hardy Cross method, Pg. 6-65, -66; check with requirements of Table B - Pg. 6-01. If heads are too low or high, revise size of pipe.

*Fire Flow Tests of Existing Systems** - The method of conducting fire flow tests to determine the amount of water available at any given point in a distribution system has been practiced by engineers of the National Board of Fire Underwriters for many years and has been checked by meter delivery and found to be sufficiently accurate for all practical determinations of available fire flow.
The number of hydrants used in a group may vary from 2 to 6, usually 3 or 4 are used, depending on the pressure, size of mains and amount of water required at the point in question. See Table A - Pg. 6-01. The flowing pressure at the hydrants is read simultaneously, by Pitot gage. The static pressure at a hydrant at or near the center of the group is read before the other hydrants are opened and the residual pressure read while the hydrants are flowing, the difference being the drop of pressure. Knowing the flowing pressure and the diameter of outlet the flow can be obtained from Table A - Pg. 6-61. We now have a certain quantity of water flowing, with a certain drop of pressure, and from this we can obtain the quantity at any other drop in pressure. The most accurate determination is obtained by using the Hazen & Williams formula, or hydraulic slide rule, but for all practical purposes the formula $Q_2 = Q_1\sqrt{h_2/h_1}$ can be used in which h_1 and h_2 are the drop of pressure for quantities Q_1 and Q_2 respectively. In practice it is desired to determine the supply available at 20 pounds, or in some cases at 10 pounds but it is not necessary, or generally desirable, to draw the pressure down to this figure; a drop of pressure at the central hydrant of 10 to 15 pounds is all that is needed and this is generally obtained by flowing not in excess of 1000 gallons from each hydrant, which means a flowing pressure of about 9 pounds from each of two 2½-inch outlets or about 35 pounds from one 2½-inch outlet. The large suction outlet can be used if necessary but it is less desirable because of irregularities in flow. It can be seen from the above that pressure and size of mains, as stated before, must influence the number of hydrants to be opened and quantity of water drawn. It must be realized that in order to obtain reasonably accurate results at 20 pounds enough water must be drawn to obtain an appreciable drop of pressure, at least 5 pounds. For equipment for tests, see Pg. 6-61.

*By R.C. Dennett, Assistant Chief Engr. Natl. Bd of Fire Underwriters.

WATER DISTRIBUTION - HYDRANT & HOSE DISCHARGE

TABLE A - DISCHARGE TABLE FOR HYDRANTS. * †

OUTLET PRESSURE MEASURED BY PITOT GAGE.

FLOWING PRESSURE IN LBS. per SQ. INCH	OUTLET DIAMETER IN INCHES											
	2 3/3	2 1/2	2 5/8	2 3/4	2 7/8	3	3 1/8	3 7/8	4	4 3/8	4 1/2	4 5/8
	U.S. GALLONS PER MINUTE											
1	150	170	180	200	220	240	260	400	430	510	540	580
2	210	240	260	290	310	340	370	570	610	720	770	810
3	260	290	320	350	380	420	450	700	740	890	940	990
4	300	340	370	410	440	480	530	810	860	1030	1090	1150
5	340	380	410	450	500	540	590	900	960	1150	1220	1290
6	370	410	450	500	540	590	640	990	1050	1260	1340	1410
7	400	440	490	540	590	640	690	1070	1140	1360	1440	1520
8	430	480	520	570	630	680	740	1140	1220	1450	1540	1620
9	450	500	550	610	670	730	790	1210	1290	1540	1640	1720
10	480	530	580	640	700	760	830	1280	1360	1630	1730	1820
11	500	560	610	670	730	800	870	1340	1430	1710	1810	1910
12	520	580	640	700	770	840	910	1400	1490	1780	1890	1990
13	550	610	670	730	800	870	950	1450	1550	1850	1960	2070
14	570	630	690	760	830	900	980	1510	1610	1920	2040	2150
15	590	650	720	790	860	940	1020	1560	1660	1990	2110	2220
16	610	670	740	810	890	970	1050	1620	1720	2060	2180	2300
17	620	690	760	840	910	1000	1080	1660	1770	2120	2240	2370
18	640	710	780	860	940	1030	1110	1710	1820	2180	2310	2440
19	660	730	810	890	960	1050	1140	1760	1870	2240	2370	2510
20	680	750	830	910	990	1080	1170	1800	1920	2290	2430	2570
22	710	790	870	950	1040	1130	1230	1890	2020	2400	2550	2700
24	740	820	910	1000	1090	1180	1290	1970	2110	2510	2660	2810
26	770	860	940	1040	1130	1230	1340	2050	2190	2620	2770	2930
28	800	890	980	1070	1170	1280	1390	2130	2280	2720	2880	3010
30	830	920	1010	1110	1210	1320	1430	2210	2350	2820	2980	3150
32	860	950	1050	1150	1260	1370	1480	2280	2430	2910	3080	3250
34	880	980	1080	1180	1290	1410	1530	2350	2510	3000	3170	3350
36	910	1010	1110	1220	1330	1450	1580	2420	2580	3080	3260	3440
38	930	1040	1140	1250	1370	1490	1620	2480	2650	3170	3350	3540
40	960	1060	1170	1290	1400	1530	1660	2550	2720	3250	3440	3630

*Computed with coefficient, C=0.90, to nearest 10 gals. per min.

EQUIPMENT FOR HYDRANT FLOW TESTS.

The equipment necessary consists of a hydrant cap tapped to take a pressure gage, an adequate supply of pitot blades and 50 pound gages, and one 100 or 200 pound gage, depending upon the static pressure on the system. A commercial type pitometer is shown in Fig. C - Pg. 6-80. If the hydrants used have two or more outlets a pressure gage on one outlet while another outlet is flowing will give approximately the same results as the use of a pitot tube. The pitot tube used in determining discharges from hydrant outlets, held at the center of the stream about half the diameter in front of the outlet, has a straight blade about 4 inches long, equipped with a union or threaded connection for the gage; the latter, for most convenient use, is 3 inch graduated in half pounds, from 0 to 50 pounds.**

** By R.C. Dennett, Engr. Natl. Bd. of Fire Underwriters.

TABLE B - FIRE STREAM & HOSE DATA. ††

Nozzle pressures by Pitot, psi	SIZE OF NOZZLE IN INCHES																			
	1				1 1/8				1 1/4				1 3/8				1 1/2			
	Discharge, gpm	Pressure loss 100 ft 2 1/2-in. hose, psi	Vertical reach, ft. of stream	Horizontal reach, ft. of stream	Discharge, gpm	Pressure loss 100 ft 2 1/2-in. hose, psi	Vertical reach, ft	Horizontal reach, ft	Discharge, gpm	Pressure loss 100 ft 2 1/2-in. hose, psi	Vertical reach, ft	Horizontal reach, ft	Discharge, gpm	Pressure loss 100 ft 3-in. hose, psi	Vertical reach, ft	Horizontal reach, ft	Discharge, gpm	Pressure loss 100 ft 3-in. hose, psi	Vertical reach, ft	Horizontal reach, ft
20	132	4.8	35	37	167	7.3	36	38	206	10.6	36	39	250	5.8	36	40	298	8.1	37	42
25	148	5.8	43	42	187	8.9	44	44	230	13.1	45	46	280	7.2	45	47	333	10.1	46	49
30	162	6.8	51	47	205	10.5	52	50	253	15.5	52	52	307	8.6	53	54	365	11.9	54	56
35	175	7.9	58	51	221	12.1	59	54	273	17.8	59	58	331	9.9	60	59	394	13.7	62	62
40	187	8.9	64	55	237	13.8	65	59	292	20.0	65	62	354	11.2	66	64	422	15.5	69	6[illegible]
45	198	9.9	69	58	251	15.3	70	63	309	22.2	70	66	376	12.5	72	68	447	17.3	74	71
50	209	10.9	73	61	265	16.8	75	66	326	24.7	75	69	396	13.8	77	72	472	19.1	79	7[illegible]
55	219	11.9	76	64	277	18.3	79	69	342	27.2	80	72	415	15.1	81	75	494	20.8	83	76
60	229	12.8	79	67	290	19.8	83	72	357	29.6	84	75	434	16.4	85	77	517	22.6	87	80
65	238	13.8	82	70	301	21.3	86	75	372	31.7	87	78	451	17.6	88	79	537	24.3	90	82
70	247	14.8	85	72	313	22.9	88	77	386	33.9	90	80	469	18.8	91	82	558	26.0	92	84
75	256	15.8	87	74	324	24.5	90	79	399	36.1	92	82	485	20.0	93	84	578	27.8	94	86
80	264	16.7	89	76	335	26.1	92	81	413	38.6	94	84	500	21.2	95	86	596	29.5	96	88
85	272	17.7	91	78	345	27.7	94	83	425	40.8	96	87	516	22.5	97	88	614	31.2	98	90
90	280	18.7	92	80	355	29.3	96	85	438	43.1	98	89	531	23.8	99	90	633	32.9	100	91

NOTES:
1. The above values of the discharge and pressure loss in 2½ and 3 inch best quality rubber lined hose are those given by National Board of Fire Underwriters.
2. For inside hand lines 2½ inch hose lines with 1⅛ inch shut off nozzles are generally used.
3. For fighting large fires from the outside, 1½ inch nozzles are usually used with 3 inch hose lines or siamesed 2½ inch lines. Maximum length of hose 400 to 500 feet.
4. For residential areas, 175 g.p.m. fire streams are standardized as satisfactory, and for business districts of ordinary character 250 g.p.m. stream.
5. The ordinary capacity of pumper is 750 g.p.m. which should be supplied by one hydrant.

† From Natl. Bd. of Fire Underwriters. †† From Davis, Handbook of Applied Hydraulics, McGraw-Hill

WATER DISTRIBUTION – FLOW IN PIPES-1

HAZEN & WILLIAMS FORMULA

$$V = 1.318\, C r^{0.63} S^{0.54}$$

Where V = mean Velocity in feet per second, r = hydraulic radius in feet, S = hydraulic Slope in feet per foot of length, C = Hazen & Williams Coefficient of roughness.

QUANTITY OF FLOW FORMULA

$$Q = AV$$

Where Q = flow in cubic feet per second, A = cross-sectional Area of pipe in square feet, V = mean Velocity in feet per second.

TABLE A – VALUES OF "C" IN HAZEN AND WILLIAMS FORMULA FOR VARIOUS KINDS OF PIPE.

KIND OF PIPE	"C"
CAST IRON	
New well laid	130
4 to 6 years old	120
10 to 12 years old	110
13 to 20 years old	100
26 to 35 years old (4" to 10" sizes)	80
37 to 47 years old (12" to 60" sizes)	80
ASBESTOS-CEMENT	140
CEMENT-LINED PIPE	
Applied by hand	125
Centrifugally applied	140
RIVETED STEEL PIPE	
New (66" to 144" sizes)	110
10 years old (66" to 144" sizes)	100
Over 10 years old	95
2", 2½" & 3" PIPE	
Very smooth & straight Brass, Tin	140
Ordinary straight Brass, Tin, etc.	130
Smooth New Iron	120
Ordinary Iron	100

KIND OF PIPE	"C"
Old Iron	80
Very rough	60
Badly tuberculated	40
WROUGHT IRON (⅛" to 1½" Sizes)	
Very smooth and straight	140
Smooth New Iron	120
Ordinary Iron	100
Old Iron	80
Very rough	60
BRASS PIPE (0.03 to 1.2 Sizes)	130
(May also be used for straight Lead, Tin & drawn Copper Pipes)	
TILE (Good condition)	110
WOOD STAVE OR SMOOTH WOODEN PIPE	120
BRICK	100
CONCRETE	120
FIRE HOSE	
Extremely smooth	143
Rubber lined	125-140
Mill Hose	100-120
Unlined Linen Hose	85-95

TABLE B – RELATIVE CARRYING CAPACITY AND HEAD LOSS FOR VARIOUS VALUES OF "C" FOR USE WITH FLOW CHART, FIG. A - Pg. 6-63.

"C"	"K_1"	"K_2"
40	5.46	0.40
60	2.58	0.60
80	1.51	0.80
90	1.22	0.90
100	1.00	1.00
110	0.84	1.10
120	0.71	1.20
130	0.62	1.30
140	0.54	1.40

Explanation:

1. To determine loss of head with value of "C" other than 100, multiply the loss of head found in Fig. A - Pg. 6-63 by the "K_1" value given in table at left.

2. To determine quantity of flow with value of "C" other than 100, multiply the quantity of flow found in Figure A - Pg. 6-63 by the "K_2" value given in table at left.

WATER DISTRIBUTION – FLOW IN PIPES*-2

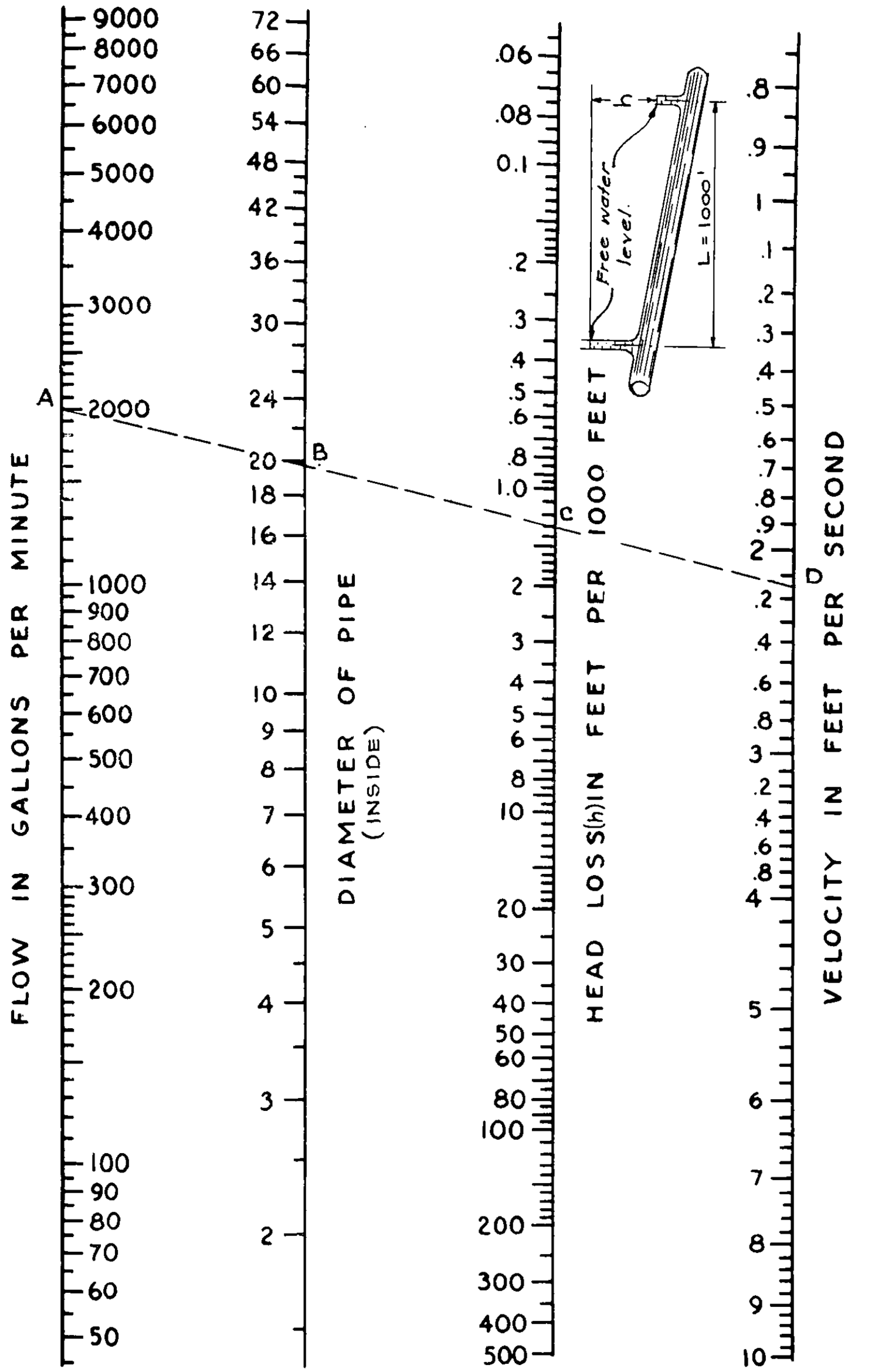


FIG. A – FLOW CHART "C" = 100*
(BASED ON HAZEN AND WILLIAMS FORMULA)

USE OF FIG. A*

Knowing any two of the following: FLOW, DIAMETER, HEAD LOSS, VELOCITY, the other two values can be found by placing a straight-edge on the factors known and reading desired factors (Known A & B desired C & D.)

TABLE B – CONVERSION OF FLOW.

Gals/Min.	Cu.Ft./Sec.	Gallons/Day
10	0.022	14,400
20	0.045	28,800
30	0.067	43,200
40	0.089	57,600
50	0.111	72,000
60	0.134	86,400
70	0.156	100,800
80	0.178	115,200
90	0.201	129,600
100	0.223	144,000
120	0.27	172,800
140	0.31	201,600
160	0.36	230,400
180	0.40	259,200
200	0.45	288,000
220	0.49	316,800
240	0.54	345,600
260	0.58	374,400
280	0.63	403,200
300	0.67	432,000
350	0.78	504,000
400	0.89	576,000
450	1.00	648,000
500	1.11	720,000
550	1.23	792,000
600	1.34	864,000
700	1.56	1,008,000
800	1.78	1,152,000
900	2.01	1,296,000
1000	2.23	1,440,000
1100	2.45	1,584,000
1200	2.67	1,728,000
1300	2.90	1,872,000
1400	3.12	2,016,000
1500	3.34	2,160,000
1600	3.57	2,304,000
1700	3.79	2,448,000
1800	4.01	2,592,000
1900	4.23	2,736,000
2000	4.46	2,880,000
3000	6.68	4,320,000
4000	8.92	5,760,000
5000	11.14	7,200,000
6000	13.36	8,640,000

*See Table B, Page 6-62, for use of Fig. A with values of "C" other than 100.

WATER DISTRIBUTION - FLOW IN PIPES - 3

TABLE A - FLOW OF WATER IN NEW HOUSE SERVICE PIPES.*

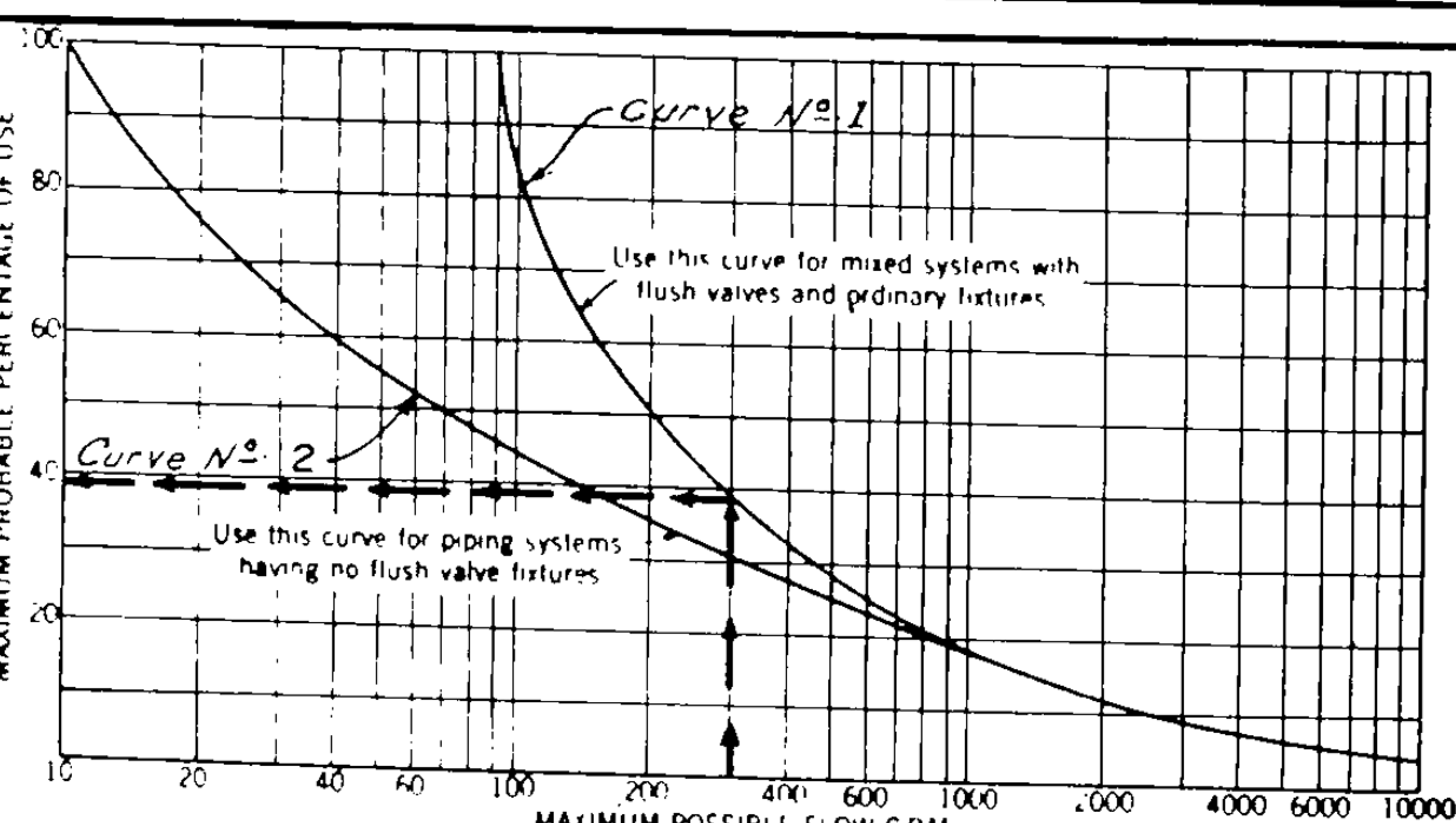
Pressure in main pounds per square inch	Discharge in cubic feet per minute						
	Nominal internal diameter of pipe (inches)						
	½	¾	1	1½	2	3	4
Through 35 feet of service pipe, no back pressure							
30	1.10	3.01	6.13	16.58	33.34	88.16	173.85
40	1.27	3.48	7.08	19.14	38.50	101.80	200.75
50	1.42	3.89	7.92	21.40	43.04	113.82	224.44
60	1.56	4.26	8.67	23.44	47.15	124.68	245.87
75	1.74	4.77	9.70	26.21	52.71	139.39	274.89
100	2.01	5.50	11.20	30.27	60.87	160.96	317.41
130	2.29	6.28	12.77	34.51	69.40	183.52	361.91
Through 100 feet of service pipe, no back pressure							
30	0.66	1.84	3.78	10.40	21.30	58.19	118.13
40	0.77	2.12	4.36	12.01	24.59	67.19	136.41
50	0.86	2.37	4.88	13.43	27.50	75.13	152.51
60	0.94	2.60	5.34	14.71	30.12	82.30	167.06
75	1.05	2.91	5.97	16.45	33.68	92.01	186.78
100	1.22	3.36	6.90	13.99	38.89	106.24	215.68
130	1.39	3.83	7.86	21.66	44.34	121.14	245.91
Through 100 feet of service pipes, and 15 feet vertical rise							
30	0.55	1.52	3.11	8.57	17.55	47.90	96.17
40	0.66	1.81	3.72	10.24	20.95	57.20	116.01
50	0.75	2.06	4.24	11.67	23.87	65.18	132.20
60	0.83	2.29	4.70	12.94	26.48	72.28	146.61
75	0.94	2.59	5.32	14.64	29.96	81.79	165.90
100	1.10	3.02	6.21	17.10	35.00	95.55	193.82
130	1.26	3.48	7.14	19.66	40.23	109.82	222.75
Through 100 feet of service pipe, and 30 feet vertical rise							
30	0.44	1.22	2.50	6.80	14.11	38.63	78.54
40	0.55	1.53	3.15	8.68	17.79	48.68	98.98
50	0.65	1.79	3.69	10.16	20.82	56.98	115.87
60	0.73	2.02	4.15	11.45	23.45	64.22	130.59
75	0.84	2.32	4.77	13.15	26.95	73.76	149.99
100	1.00	2.75	5.65	15.58	31.93	87.38	177.67
130	1.15	3.19	6.55	18.07	37.92	101.33	206.04

TABLE B - EQUIVALENT PIPE SIZES.*

Diam., in.	Diam., in.															
	3	4	5	6	8	10	12	14	16	18	20	22	24	30	36	48
48									15.59	11.61	8.92	7.03	5.65	3.24	2.05	1
44								17.50	12.54	9.34	7.17	5.66	4.55	2.01	1.65	
40							20.23	13.47	9.85	7.31	5.61	4.44	3.57	2.05	1.26	
36							15.58	8.41	7.59	5.65	4.34	3.42	2.74	1.58	1.	
33					34.55	19.78	12.54	8.52	6.11	4.55	3.49	2.75	2.21	1.27		
30					27.00	15.54	9.85	6.54	4.80	$\boxed{3.57}$	2.74	2.19	1.74	1.		
27				42.95	16.61	9.96	7.59	5.16	3.70	2.75	2.11	1.67	1.34			
24			50.50	32.00	15.58	8.92	5.65	3.84	2.75	2.05	1.57	1.24	1.			
22		70.96	40.65	25.73	12.53	7.17	4.55	3.09	2.16	1.65	1.28	1.				
20		55.96	32.05	20.29	9.88	5.66	3.58	2.43	1.71	1.30	1.					
18		42.01	24.63	15.58	7.25	4.34	2.75	1.87	1.34	1.						
16	65.77	32.01	18.31	11.60	5.65	3.23	2.05	1.39	1.							
14	47.14	22.94	13.15	8.32	4.05	2.32	1.47	1.								
12	32.05	15.60	8.93	5.65	2.75	1.57	1.									
10	20.31	9.88	5.66	3.58	1.74	1.										
8	11.63	5.66	3.24	2.05	1.											
6	5.66	2.75	1.58	1.												
5	3.58	1.75	1.													
4	2.05	1.														
3	1.															

The figures shown above indicate how many pipes of the sizes printed at the top are equivalent to one pipe of the size in the first column.

__EXAMPLE__: Given: 30" Pipe.
__Find__: Equivalent number of 18" Pipes.
Table B. above, gives 3.57, use 4-18" Pipes.



- BUILDING SUPPLY -

FIG. C - FACTORS OF USAGE.**

EXAMPLE OF USE OF FIG. C

Assume maximum flow 300 g.p.m. (In a specific case this value would be computed using Tables E & G, Pg. 6-00 and number of fixtures involved.)

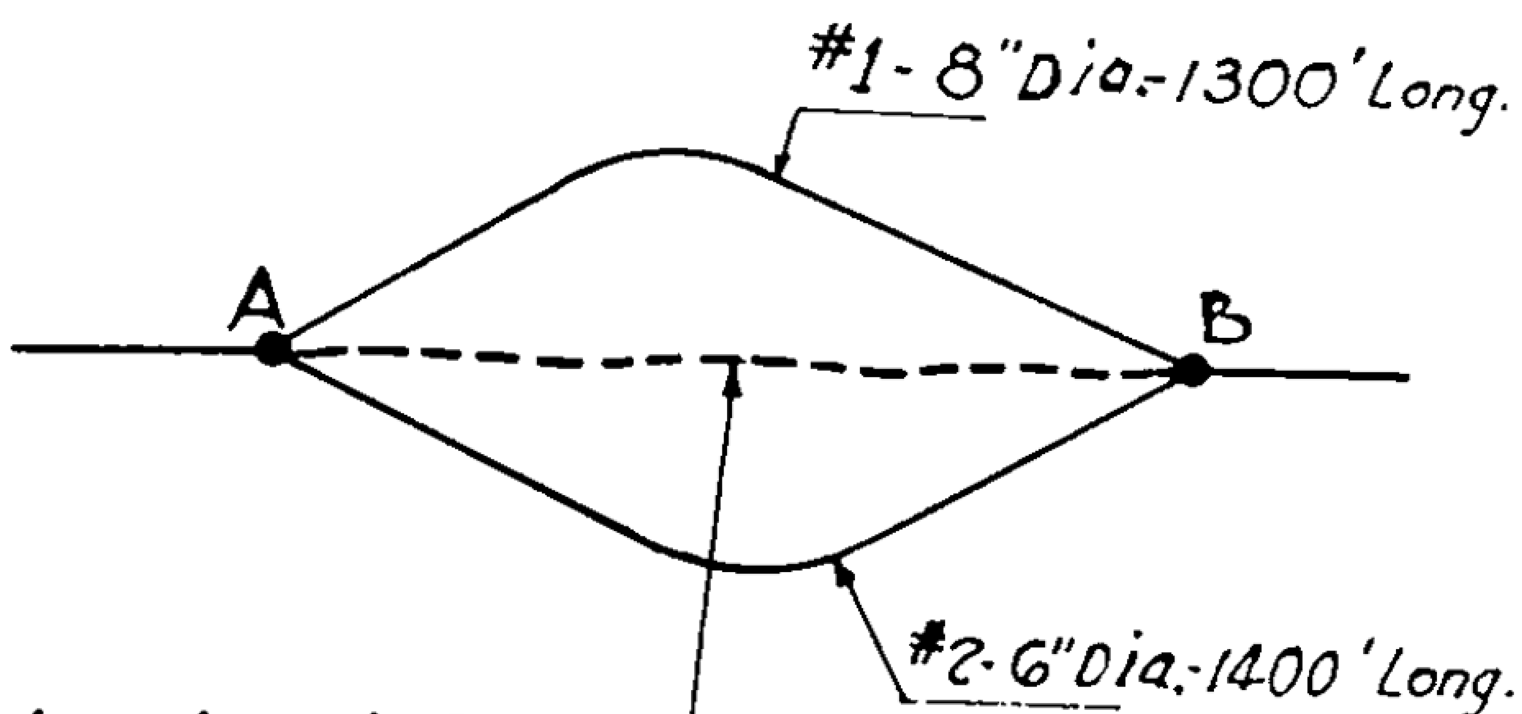
Using Curve Nº1 in Fig. C at left (flush valves to be used) the factor of usage will be 39% and the probable flow will be 300 × .39 = 117 g.p.m. This 117 g.p.m. is the average flow which should be provided to the bldg. from the outside supply.

__NOTE__: Chart may not be conservative for plants such as gymnasium and manufacturing plants where total demands occur within certain hours. Factor of usage may be 100%.

* Data from Flinn, Weston & Bogert, Waterworks Handbook, Mc Graw-Hill
** Chart from Heating, Ventilating, Air Conditioning Guide, 1943, Chapt. 46.

WATER DISTRIBUTION-EQUIVALENT PIPES

PIPES IN PARALLEL



Example:

Given:
Sizes and lengths of parallel pipes #1 and #2 as shown in above figure.

Required:
Equivalent Pipe (Length = 1000 feet assumed).

Solution:

1. Loss of head through Pipe #1 must always equal loss of head through Pipe #2 between points A & B.
2. Assume any arbitrary head loss (convenient for use in Fig. A, Page 6-63) say 10 feet.
3. Calculate head loss in feet per 1000 feet for pipes #1 & #2.

$$\#1 - \frac{10}{1300} \times 1000 = 7.7'/1000'$$

$$\#2 - \frac{10}{1400} \times 1000 = 7.1'/1000'$$

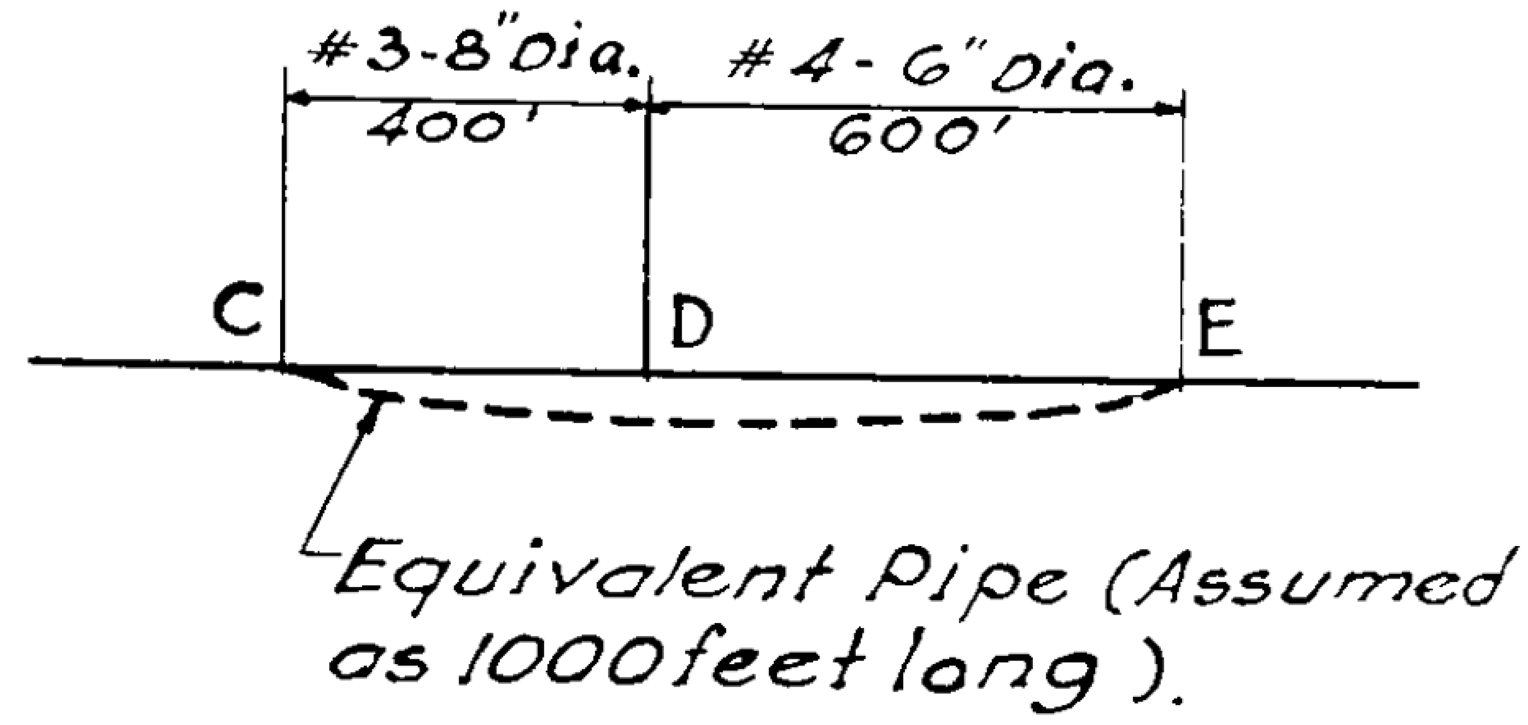
4. Use Fig. A, Page 6-63 to find flow in gallons per minute.

#1 - 8" Diam.	7.7' loss	495 Gals/Min.
#2 - 6" Diam.	7.1' loss	220 Gals./Min.

Total Q through both pipes = 715 Gals./Min.

5. Using Fig. A, Page 6-63 with head loss = 10'/1000' & Q = 715 Gals/Min. the equivalent pipe size is found to be 8.8" Diameter.

PIPES IN SERIES



Example:

Given:
Sizes and lengths of pipes #3 and #4 as shown in above figure.

Required:
Equivalent Pipe (Length = 1000 feet assumed).

Solution:

1. Quantity of water flowing through pipe #3 and pipe #4 is the same.
2. Assume any arbitrary flow through pipes #3 and #4 (convenient for use with Fig. A, Page 6-63) say 500 Gals./Min.
3. Using Fig. A, Page 6-63 find head loss for pipes #3 and #4.

	Head loss
#3 - 8" Dia. - 400' Long	
500 Gals./Min.	0.4 × 8.0 = 3.2 ft.
#4 - 6" Dia. - 600' Long	
500 Gals./Min.	0.6 × 33.0 = 19.8 "

Total head loss in both pipes = 23.0 ft.

4. Using Fig. A, Page 6-63 with head loss = 23.0'/1000' and Q = 500 Gals./Min. the equivalent pipe size is found to be 6.5" Diameter.

WATER DISTRIBUTION - FLOW IN PIPES - HARDY CROSS†

BASIC EQUATIONS

$$\begin{cases} h_f = k\,Q_m^{1.85} \\ C_f = \dfrac{\text{Difference of } h_f}{1.85 \times \sum k\,Q_m^{0.85}} \end{cases}$$

h_f = loss of head factor.
k = Value in Table B - below. ††
Q = total flow (100 g.p.m. in example below).
Q_m = % of Q in any pipe.
C_f = correction factor to Q_m.

Note: hf must balance in any loop. This involves a process of trial & error.

EXAMPLE: *Given* system shown in Fig. A, Q = 100 g.p.m. at A & D.
Required: Loss of head between A & D. *Solution*: Assume Q_m values shown thus (50) in Fig. A.
Determine k from Table B. Proceed as in First and Second Trials below.

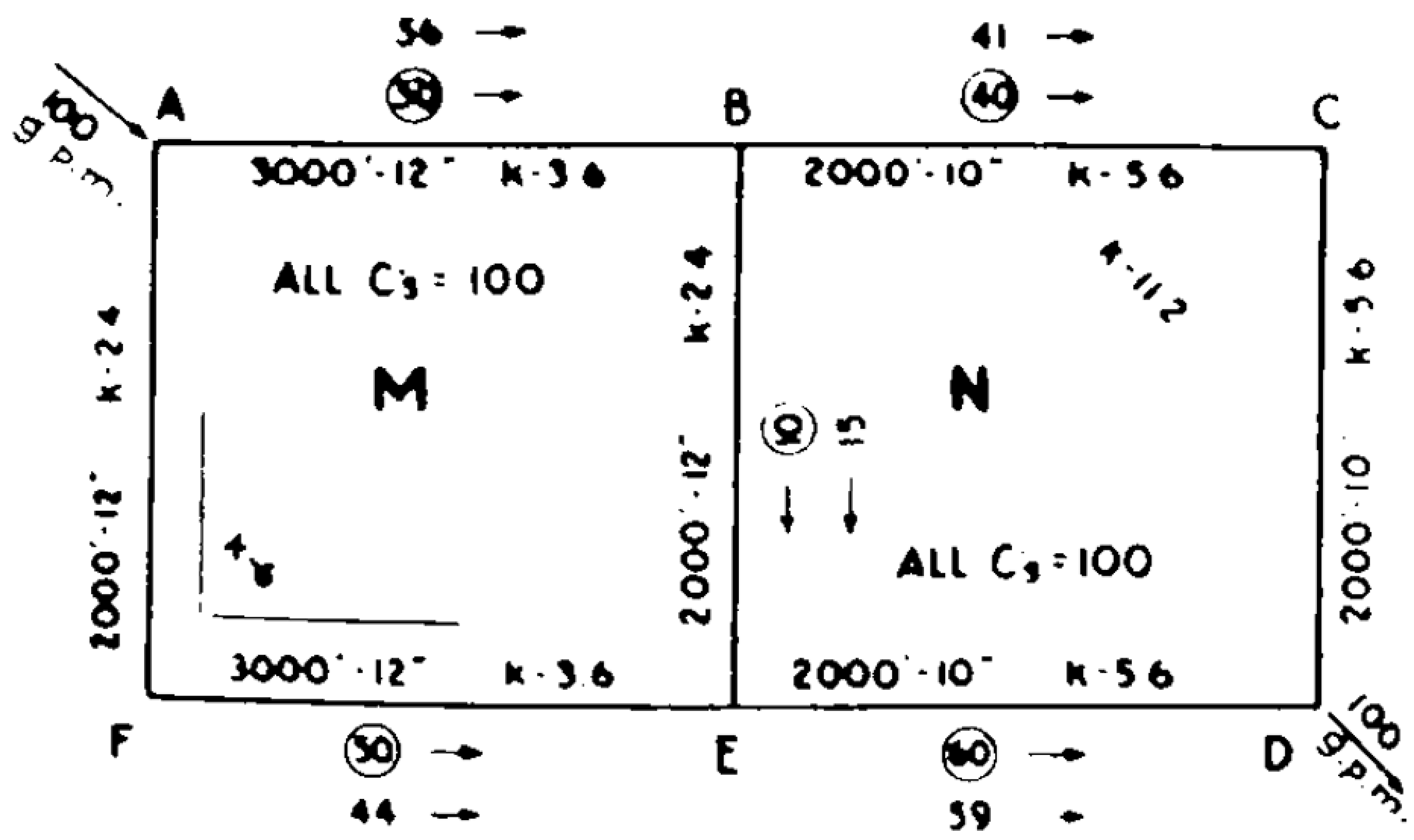


FIG. A - SYSTEM OF TWO CIRCUITS.

Note: $kQ_m^{1.85} = kQ_m^{0.85} \times Q_m$

First Trial

Circuit M

Loop	$(k \times Q_m^{0.85} = kQ_m^{0.85}) \times Q_m =$	h_f	
AB	(3.6 × 27.8 = 100) × 50 =	5000	
BE	(2.4 × 7.1 = 17) × 10 =	170	
			5170
AFE	(6.0 × 27.8 = 167) × 50 =	8330	8330
	284*		3160**

*Adding the $kQ_m^{0.85}$ = 284.
**Subtracting the h_f values = 3160.

$$C_f = \text{Correction} = \frac{3160}{1.85 \times 284} = 6.02$$

First Trial Continued:-

Circuit N

BCD	(11.2 × 23 = 268) × 40 =	10310	10310
BE	(2.4 × 7.1 = 17) × 10 =	170	
ED	(5.6 × 32.4 = 181) × 60 =	10900	11070
	456		760

$$C_f = \text{Correction} = \frac{760}{1.85 \times 456} = 0.902$$

In making this correction it should be noted that while circuit M requires a correction of 6, circuit N requires a correction of only 1. This means that the flow from A to B should be increased 6, but at point B this flow should be divided between BCD and BE so that the flow in BCD is increased only 1; therefore 1 is added to BCD and 5 is added to BE.

Second Trial

Circuit M

Loop	$(k \times Q_m^{0.85} = kQ_m^{0.85}) \times Q_m =$	h_f	
AB	(3.6 × 30.6 = 110) × 56 =	6165	
BE	(2.4 × 10.0 = 24) × 15 =	360	6525
AFE	(6.0 × 25.0 = 150) × 44 =	6600	6600
	284		75

$$C_f = \text{Correction} = \frac{75}{1.85 \times 284} = 0.143$$

Circuit N

BCD	(11.2 × 23.5 = 263) × 41 =	10800	10800
BE	(2.4 × 10.0 = 24) × 15 =	360	
ED	(5,6 × 32.0 = 179) × 59 =	10560	10920
	466		120

$$C_f = \text{Correction} = \frac{120}{1.85 \times 466} = 0.139$$

When hf balances in a circuit the assumed per cent of flow is correct. Having determined % of flow in piping, determine Q for any pipe by multiplying Qm × total Q, 100 g.p.m. in example above. With Q and size of pipe known, the total loss of head can be computed using Fig. A, Page 6-63.

TABLE B - VALUES OF K FOR 1000 FT. OF PIPE. ††

PIPE DIA.	"C" VALUES (SEE TABLE A PG. 6-61) 90	100	110	120	130	140
4	300.0	248.0	208.0	177.0	153.0	133.0
6	41.0	33.7	28.4	24.2	20.9	18.2
8	10.0	8.4	7.0	6.0	5.2	4.5
10	3.4	2.8	2.4	2.0	1.7	1.5
12	1.5	1.2	1.0	.83	.71	.62
14	.66	.55	.46	.39	.34	.30
16	.35	.29	.24	.20	.18	.15
18	.20	.16	.14	.12	.10	.09
20	.12	.10	.08	.07	.06	.05
24	.049	.04	.03	.03	.02	.02
30	.016	.013	.011	.010	.008	.007
36	.0067	.0054	.0046	.0039	.0034	.003

EXAMPLE: *Given*: D = 12", C = 100
Required: k
Solution: k = 1.2

TABLE C - VALUES OF THE 0.85 POWER OF NUMBERS.

Nº	0	1	2	3	4	5	6	7	8	9
0	0	1.0	1.8	2.5	3.2	3.9	4.6	5.2	5.9	6.5
10	7.1	7.7	8.3	8.9	9.4	10.0	10.6	11.1	11.6	12.2
20	12.8	13.3	13.8	14.4	14.9	15.4	15.9	16.5	17.0	17.5
30	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5
40	23.0	23.5	24.0	24.5	25.0	25.4	25.8	26.4	26.8	27.3
50	27.8	28.2	28.7	29.2	29.6	30.1	30.6	31.0	31.4	32.0
60	32.4	33.0	33.3	33.9	34.2	34.7	35.1	35.6	36.0	36.5
70	37.0	37.4	37.9	38.3	38.8	39.1	39.6	40.0	40.5	41.0
80	41.5	42.0	42.4	42.8	43.3	43.7	44.1	44.5	45.0	45.4
90	45.8	46.3	46.7	47.1	47.6	48.0	48.4	48.8	49.2	49.6

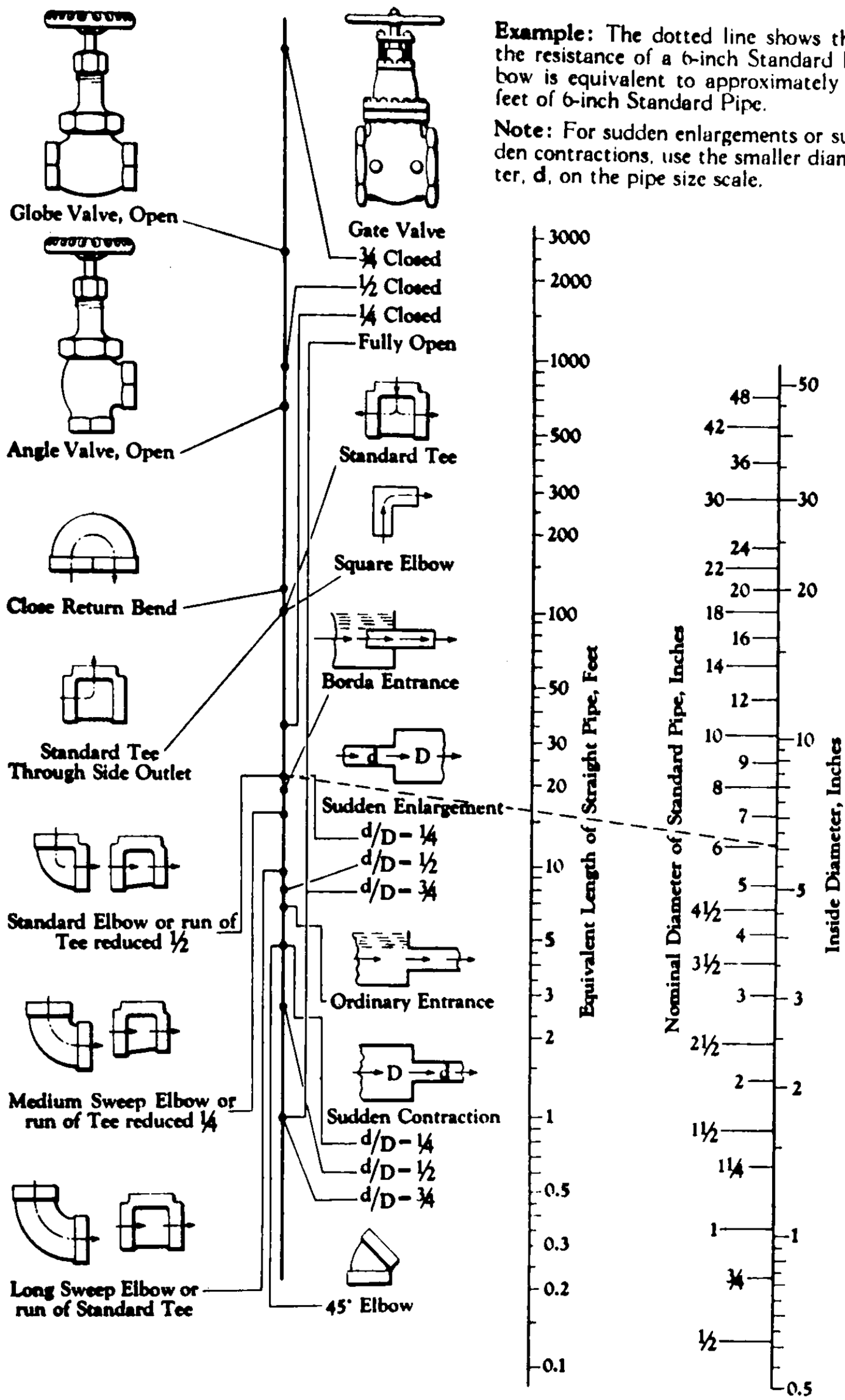
EXAMPLE: *Given*: Number 54
Required: $54^{0.85}$
Solution: $54^{0.85} = 29.6$

† Doland System for using Hardy Cross method, from Water Works & Sewage - June '1943 article by R.D. Taylor. †† Based on Hazen-Williams Formula.

WATER DISTRIBUTION-HEAD LOSS IN VALVES, FITTINGS, ETC.

Example: The dotted line shows that the resistance of a 6-inch Standard Elbow is equivalent to approximately 16 feet of 6-inch Standard Pipe.

Note: For sudden enlargements or sudden contractions, use the smaller diameter, d, on the pipe size scale.



RESISTANCE OF VALVES AND FITTINGS TO FLOW OF FLUIDS

NOTE: Head loss through check valves varies with types manufactured. Consult manufacturer for correct values.

From Crane Co. Catalog No. 41.

WATER DISTRIBUTION- CAST IRON PIPE

TABLE A - AMERICAN WATER WORKS ASSOCIATION STANDARD CAST IRON PIPE.*

NOMINAL INSIDE DIAMETER IN INCHES	CLASS "A" 100 FOOT HEAD 43 POUNDS PRESSURE		CLASS "B" 200 FOOT HEAD 86 POUNDS PRESSURE		CLASS "C" 300 FOOT HEAD 130 POUNDS PRESSURE		CLASS "D" 400 FOOT HEAD 173 POUNDS PRESSURE	
	THICKNESS IN INCHES	APPROX. WT. PER FT. IN LBS.	THICKNESS IN INCHES	APPROX. WT. PER FT. IN LBS.	THICKNESS IN INCHES.	APPROX. WT. PER FT. IN LBS.	THICKNESS IN INCHES	APPROX. WT. PER FT. IN LBS.
3"	0.39	14.5	0.42	16.2	0.45	17.1	0.48	18.0
4"	0.42	20.0	0.45	21.7	0.48	23.3	0.52	25.0
6"	0.44	30.8	0.48	33.3	0.51	35.8	0.55	38.3
8"	0.46	42.9	0.51	47.5	0.56	52.1	0.60	55.8
10"	0.50	57.1	0.57	63.8	0.62	70.8	0.68	76.7
12"	0.54	72.5	0.62	82.1	0.68	91.7	0.75	100.0
14"	0.57	89.6	0.66	102.5	0.74	116.7	0.82	129.2
16"	0.60	108.3	0.70	125.0	0.80	143.8	0.89	158.3
18"	0.64	129.2	0.75	150.0	0.87	175.0	0.96	191.7
20"	0.67	150.0	0.80	175.0	0.92	208.3	1.03	229.2
24"	0.76	204.2	0.89	233.3	1.04	279.2	1.16	306.7
30"	0.88	291.7	1.03	333.3	1.20	400.0	1.37	450.0
36"	0.99	391.7	1.15	454.2	1.36	545.8	1.58	625.0
42"	1.10	512.5	1.28	591.7	1.54	716.7	1.78	825.0

Water Hammer of ordinary intensity allowed for in the above Tables. *Weights based on 12 foot length.*

TABLE B - FEDERAL SPECIFICATIONS WW-P-421 STANDARD.

NOMINAL INSIDE DIAMETER IN INCHES	100# CLASS ** OR MAX. WORKING PRESSURE		150# CLASS *** OR MAX. WORKING PRESSURE		200# CLASS ** OR MAX. WORKING PRESSURE		250# CLASS *** OR MAX WORKING PRESSURE	
	THICKNESS IN INCHES	APPROX. WT. PER FT. IN LBS.	THICKNESS IN INCHES	APPROX. WT. PER FT. IN LBS.	THICKNESS IN INCHES.	APPROX. WT. PER FT. IN LBS.	THICKNESS IN INCHES	APPROX. WT. PER FT. IN LBS.
3	100# Class - Weights for Class B fittings. 150#, 200# & 250# Classes - weights for Class D fittings.		0.33	12.5			0.36	13.8
4			0.34	16.1			0.38	18.1
6			0.37	25.7			0.43	28.7
8			0.42	38.6	0.46	41.6	0.50	44.6
10			0.47	52.2	0.52	57.2	0.57	62.3
12			0.50	66.1	0.57	74.1	0.62	81.1
14	0.48	74.9	0.55	86.9	0.62	97.0	0.69	108.0
16	0.52	92.1	0.60	108.1	0.68	121.6	0.75	133.6
18	0.56	111.4	0.65	130.4	0.74	147.9	0.83	164.9
20	0.58	129.0	0.68	152.0	0.78	173.6	0.88	193.6
24	0.64	169.9	0.76	202.9	0.88	233.1	1.00	262.1

Water Hammer of ordinary intensity allowed for in the above Tables. Weights based on 16 foot length.

TABLE C - WATER HAMMER ALLOWANCE.

DIAMETER OF PIPE IN INCHES	WATER HAMMER LB. PER SQ. IN.	DIAMETER OF PIPE IN INCHES	WATER HAMMER LB. PER SQ. IN.
4" to 10"	120	24"	85
12" to 14"	110	30"	80
16" to 18"	100	36"	75
20"	90	42" to 60"	70

Note: The above Table shows water hammer allowances used by the American Standards Assoc.-70 East 45th St, N.Y.C. in their manual for the computation, for the strength & thickness of C.I. pipe.

Values are for average grids. Each designer of a pipe line should consider whether the conditions in his case may require a more liberal water hammer allowance. For furthur information - see method including Allievi Chart in the Handbook of Water Control by R. Hardesty M.fg. Co. - Denver, Colo.

*Data from Handbook of Cast Iron Pipe by C.I. Research Assn.
**Data from American Cast Iron Pipe Co.
***Data from Federal Specifications - WW-P-421.

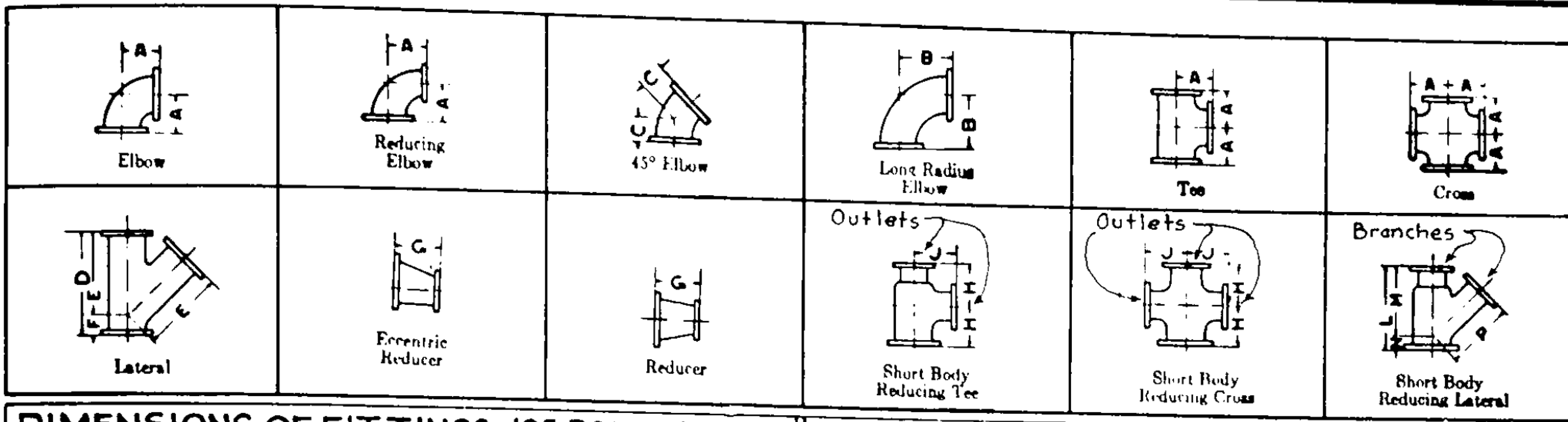
†† Adapted from U.S. Pipe & Foundry Co.

TABLE D - APPROXIMATE QUANTITIES OF MATERIALS USED PER JOINT FOR WATER SERVICE.††

NOMINAL DIAMETER IN INCHES	†POUNDS OF JOINT COMPOUND 2½" JOINT DEPTH	POUNDS OF HEMP PER JOINT	POUNDS OF LEAD IN JOINT 2" DEEP	POUNDS OF LEAD IN JOINT 2¼" DEEP	POUNDS OF LEAD IN JOINT 2½" DEEP
3"		0.18	6.00	6.50	7.00
4"	2.00	0.21	7.50	8.00	8.75
6"	3.00	0.31	10.25	11.25	12.25
8"	4.00	0.44	13.25	14.50	15.75
10"	5.00	0.53	16.00	17.50	19.00
12"	6.00	0.61	19.00	20.50	22.50
14"	7.00	0.81	22.00	24.00	26.00
16"	8.25	0.94	30.00	33.00	35.75
18"	9.25	1.00	33.80	36.90	40.00
20"	10.50	1.25	37.00	40.50	44.00
24"	13.00	1.50	44.00	48.00	52.50

† Approximate only: - will vary with kind of material used.
NOTE: - Wt. of lead is based on std. wt. = 0.41 lb. per. cu. in. This wt. may vary 15% depending on purity.

WATER DISTRIBUTION – FITTINGS & JOINTS



DIMENSIONS OF FITTINGS-125 POUNDS CLASS

Nominal Size Inside Diam.	A	B	C	D	E	F	G	Short Body Red. Tees and Crosses: Size of Outlets	H	J	Short Body Red. Laterals: Size of Br'ch's	L	M	N	P
1	3½	5	1¾	7½	5¾	1¾									
1¼	3¾	5½	2	8	6¼	1¾									
1½	4	6	2¼	9	7	2									
2	4½	6½	2½	10½	8	2½									
2½	5	7	3	12	9½	2½									
3	5½	7¾	3	13	10	3	6								
3½	6	8½	3½	14½	11½	3	6½								
4	6½	9	4	15	12	3	7								
5	7½	10¼	4½	17	13½	3½	8								
6	8	11½	5	18	14½	3½	9								
8	9	14	5½	22	17½	4½	11								
10	11	16½	6½	25½	20½	5	12								
12	12	19	7½	30	24½	5½	14								
14	14	21½	7½	33	27	6	16								
16	15	24	8	36½	30	6½	18								
18	16½	26½	8½	39	32	7	19	12 and smaller	13	15½	8 and smaller	26	25	1	27½
20	18	29	9½	43	35	8	20	14 "	14	17	10 "	28	27	1	29½
24	22	34	11	49½	40½	9	24	16 "	15	19	12 "	32	31½	½	34½
30	25	41½	15	59	49	10	30	20 "	18	23	14 "	39	39	0	42
36	28	49	18				36	24 "	20	26					
42	31	56½	21				42	24 "	23	30					
48	34	64	24				48	32 "	26	34					

DIMENSIONS OF FITTINGS-250 POUNDS CLASS

Nominal Size Inside Diam.	A	B	C	D	E	F	G	Short Body Reducing Tees and Crosses: Size of Outlets	H	J	Short Body Red. Laterals: Size of Br'ch's	L	M	N	P
1	4	5	2	8½	6½	2									
1¼	4½	5½	2½	9½	7¼	2¼									
1½	4½	6	2¾	11	8½	2½									
2	5	6½	3	11½	9	2½									
2½	5½	7	3½	13	10½	2½									
3	6	7¾	3½	14	11	3	6								
3½	6½	8½	4	15½	12½	3	6½								
4	7	9	4½	16½	13½	3	7								
5	8	10¼	5	18½	15	3½	8								
6	8½	11½	5½	21½	17½	4	9								
8	10	14	6	25½	20½	5	11								
10	11½	16½	7	29½	24	5½	12								
12	13	19	8	33½	27½	6	14								
14 O.D.	15	21½	8½	37½	31	6½	16								
16 "	16½	24	9½	42	34½	7½	18								
18 "	18	26½	10	45½	37½	8	19	12 and smaller	14	17	8 and smaller	34	31	3	32½
20 "	19½	29	10½	49	40½	8½	20	14 "	15½	18½	10 "	37	34	3	36
24 "	22½	34	12	57½	47½	10	24	16 "	17	21½	12 "	44	41	3	43
30 "	27½	41½	15				30	20 "	20½	25½					

FIG. A – AMERICAN STANDARD FLANGED FITTINGS.*

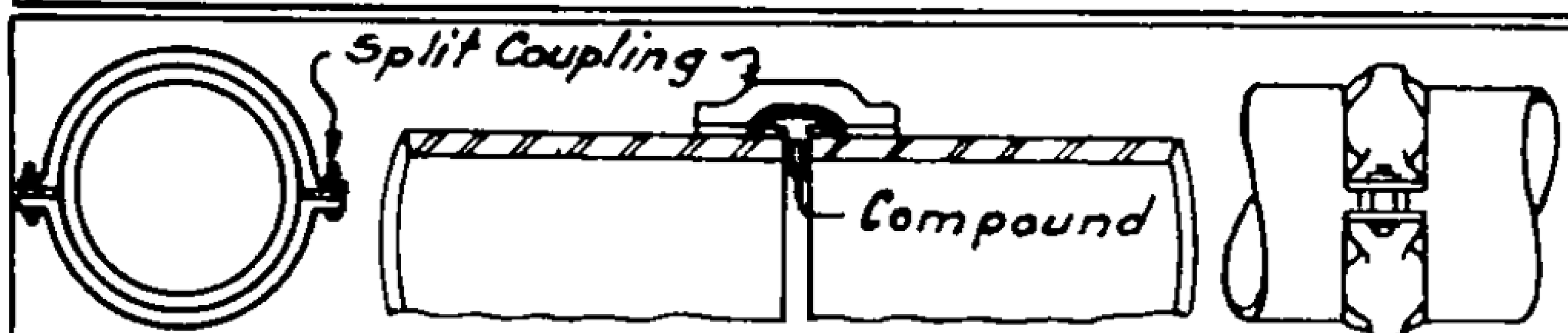
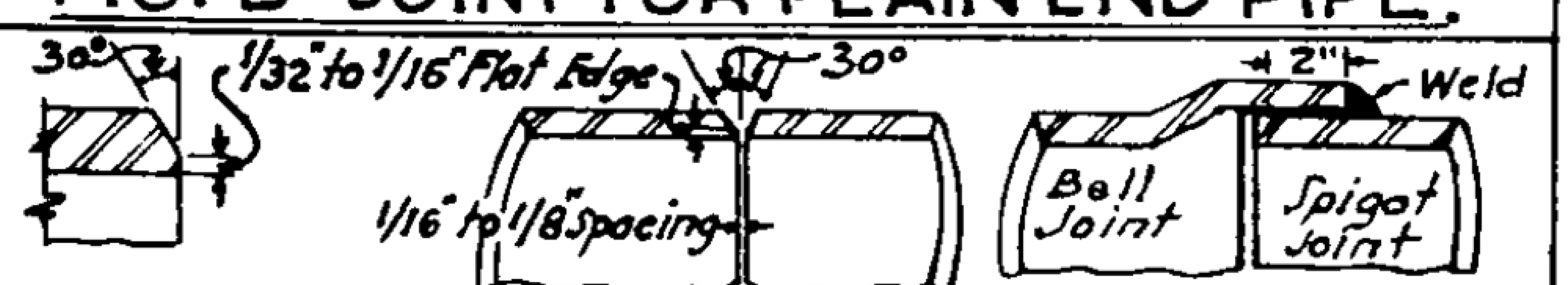


FIG. B – JOINT FOR PLAIN END PIPE.



FOR OIL & GASOLINE LINES. FOR WATER LINES.

FIG. C – WELDED JOINT FOR STEEL PIPE.

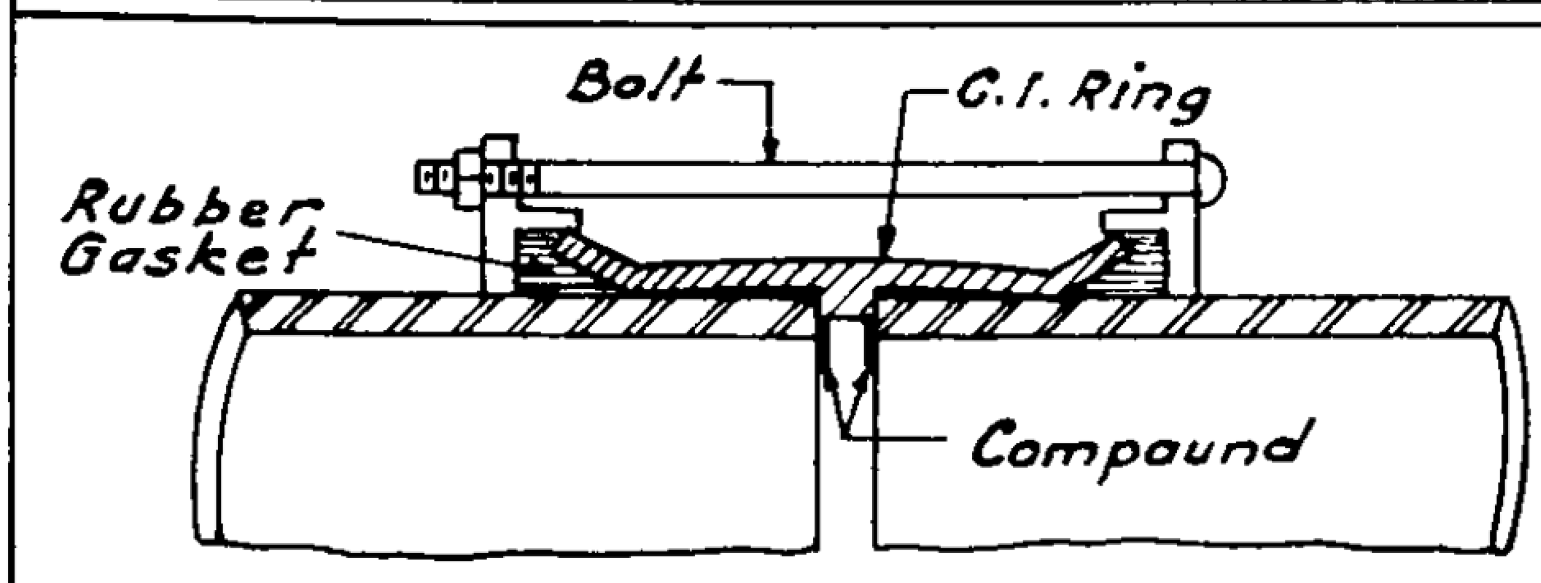
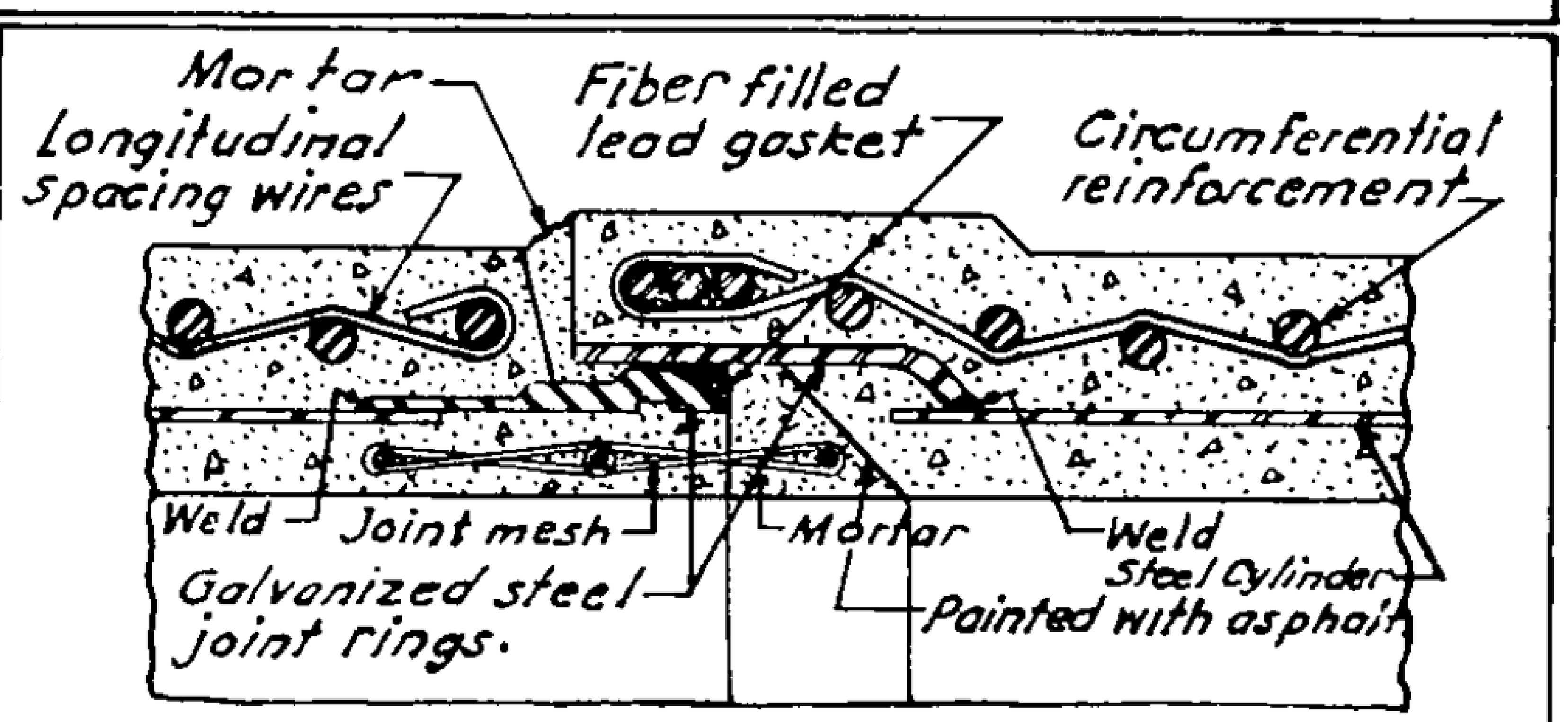
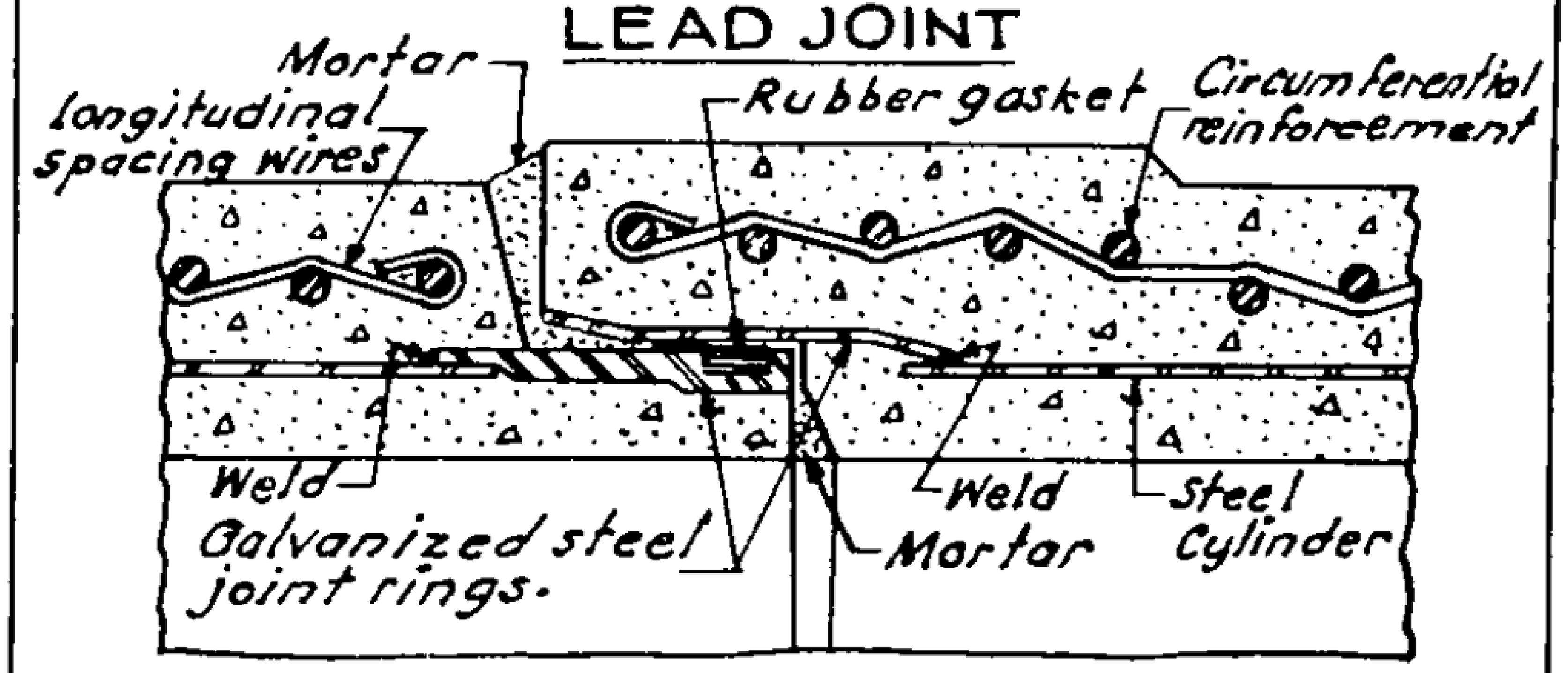


FIG. D – DRESSER COUPLING.

Use on plain end pipe for flexible joints and expansion joints.



LEAD JOINT



RUBBER JOINT

FIG. E – JOINT DETAILS OF CONCRETE PRESSURE PIPE (LOCK JOINT).†

*Data from Handbook of Cast Iron Pipe by Cast Iron Research Association.

† Adapted from Lock Joint Co.

WATER DISTRIBUTION – CEMENT-ASBESTOS PIPE

TABLE A – CEMENT-ASBESTOS PIPE (TRANSITE)

PIPE SIZE* (INCHES)	CLASS 50 SHELL THICKNESS (INCHES)	CLASS 50 WEIGHT PER LIN. FT. (lbs.)	CLASS 100 SHELL THICKNESS (INCHES)	CLASS 100 WEIGHT PER LIN. FT. (lbs.)	CLASS 150 SHELL THICKNESS (INCHES)	CLASS 150 WEIGHT PER LIN. FT. (lbs.)	CLASS 200 SHELL THICKNESS (INCHES)	CLASS 200 WEIGHT PER LIN. FT. (lbs.)
3	.33	3.6	.35	3.8	.44	4.6	.60	6.6
3½	.33	4.2	.35	4.4	.45	5.4	.60	7.5
4	.33	4.7	.35	5.0	.45	6.0	.60	8.4
4½	.34	5.4	.36	5.6	.48	7.3	.64	10.0
5	.35	6.2	.37	6.4	.51	8.6	.68	11.8
6	.36	7.6	.38	7.8	.55	10.7	.75	15.4
7	.38	9.3	.41	9.8	.61	14.1	.82	19.5
8	.42	11.7	.44	11.9	.65	16.8	.88	23.7
10	.44	15.2	.59	19.8	.85	28.0	1.10	37.0
12	.48	19.8	.68	27.6	.98	38.6	1.24	49.6
14	.52	24.8	.78	36.6	1.13	51.6	1.44	67.0
16	.56	30.6	.88	47.0	1.25	65.0	1.65	87.8
18	.59	35.9	.97	58.2	1.39	81.2	1.87	112.0
20	.63	42.5	1.07	71.2	1.53	99.5	2.09	139.5
24	.69	55.5	1.25	99.3	1.82	141.5	2.48	199.0
30	.90	89.2	1.54	150.6	2.29	221.0	3.12	310.0
36	1.09	126.3	1.83	211.0	2.80	318.0	3.74	435.0

__PIPE SIZE__ is inside diameter except sizes 4", 6" and 8" in Class 150, which are 3.95", 5.85" and 7.85" respectively. __CLASS__ of pipe is same as allowable working pressure in lbs. per sq. in. Furnished in straight lengths only, standard length = 13 ft.

TABLE B – MAXIMUM SIZE OF TAPS

CORPORATION STOP MAX. SIZE (INCHES)	SIZE OF TAPPED PIPE: TAPPED DIRECTLY INTO PIPE WALL	TAPPED THROUGH SPECIAL SIMPLEX COUPLING	TAPPED WITH SERVICE CLAMPS
¾	3" to 7"		
1	8" & up		
1¼		2" to 5"	
1½		6" to 8"	
2			8" & up

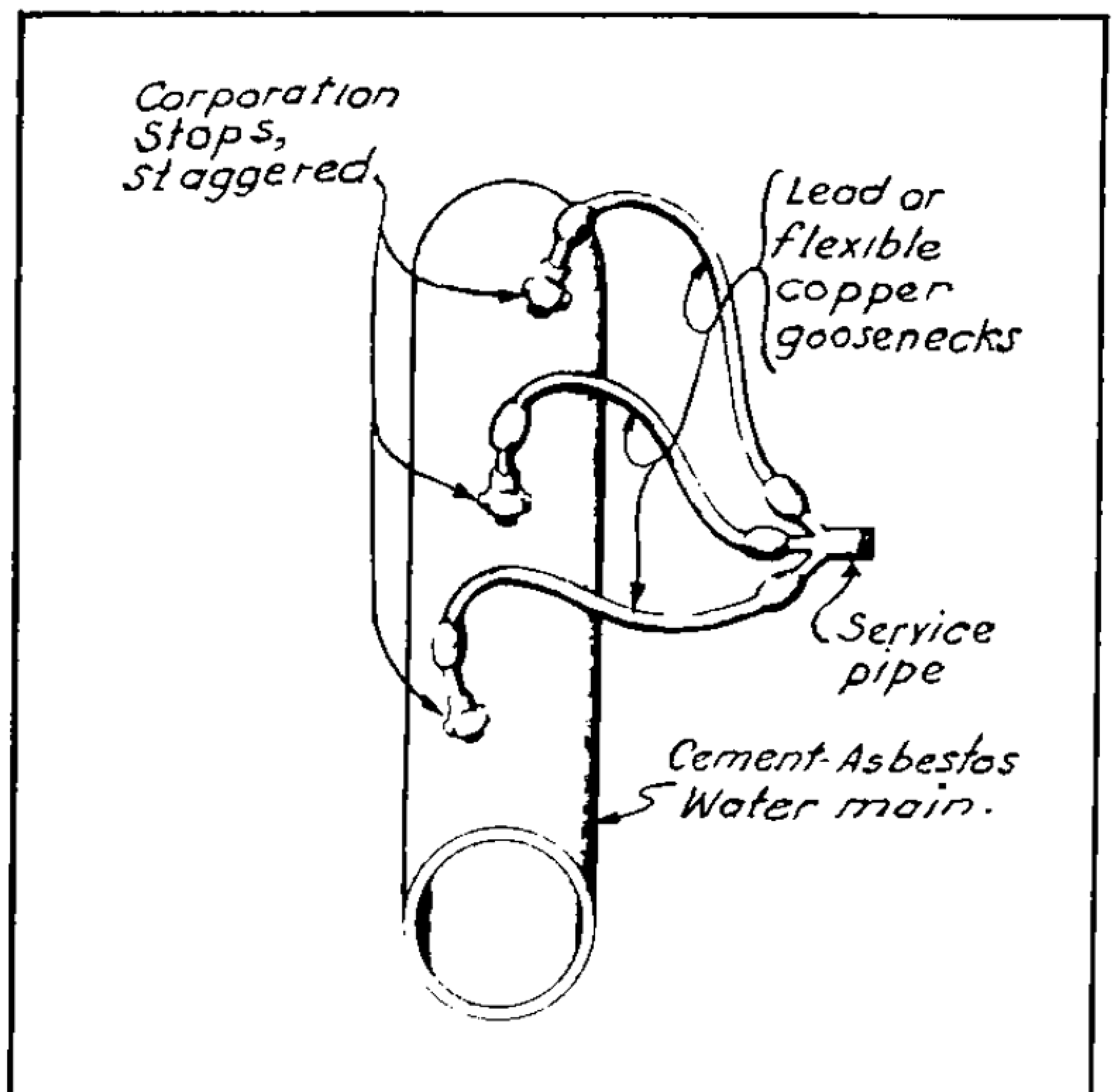


FIG. C – MULTIPLE CORPORATION STOPS AND GOOSENECKS.

Recommended for large service connections.

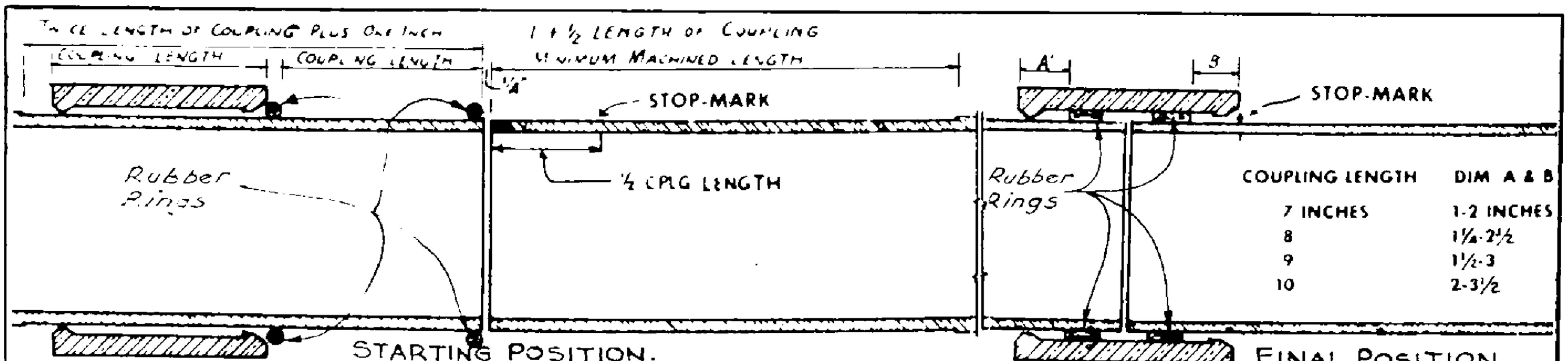


FIG. D – SIMPLEX COUPLING FOR TRANSITE PRESSURE PIPE.

__FITTINGS:__ Standard Cast-Iron with bells at all joints to Transite pipe recommended. Some sizes of Transite pipe require oversize bell fittings to provide minimum ¼" joint space. Standard steel, brass or copper fittings also used.

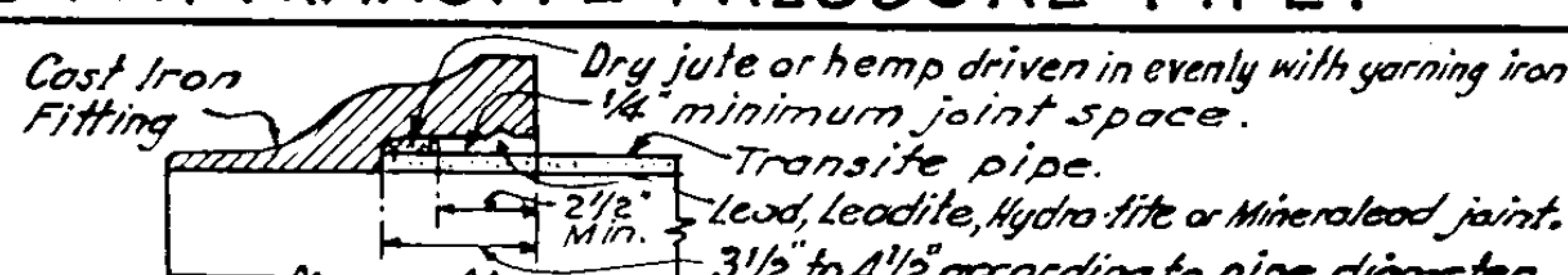


FIG. E – JOINT FOR C.I. FITTING ON TRANSITE PIPE.

All data from Johns-Manville Corporation.

WATER DISTRIBUTION — WOOD STAVE PIPE

TABLE A - DOUGLAS FIR CONTINUOUS STAVE STEEL BANDED PIPE.

INSIDE PIPE Diam. (INCHES)	STAVE THICKNESS (INCHES)	MAX. HEAD (FEET)	WEIGHT PER LIN. FT. (lbs.)*
4	1¼	400	4.95
6	1¼	400	6.84
8	1¼	400	8.73
10	1⅜	400	11.8
12	1⅜	400	13.9
14	1⅜	400	16.0
16	1 7/16	400	18.9
18	1 7/16	370	21.1
20	1 7/16	330	23.2
24	1½	290	28.8
"	2	380	39.2
30	1½	230	35.6
"	2	310	48.3
36	1⅝	210	46.1
"	2⅛	270	61.1
42	1⅝	180	53.5
"	2⅛	230	70.7
48	1⅝	150	60.8
"	2⅛	200	80.4
60	2⅛	160	100
"	2½	190	118
"	2⅝	210	124
"	3⅝	280	174
72	2½	160	140
"	2⅝	170	148
"	3⅝	240	207
84	2⅝	150	172
"	3⅝	200	240

*Untreated staves only.
BANDS: Mild steel ϕ rods ult. tensile strength 55,000 to 65,000 p.s.i., allowable working stress 15,000 p.s.i.

TABLE B - DOUGLAS FIR WIRE WOUND PIPE.

INSIDE PIPE Diam. (INCHES)	MAXIMUM HEAD 100 FEET: SHELL THICKNESS (INCHES)	WIRE † GAGE No. §	WIRE † SPACING (INCHES)	WEIGHT PER LIN. FT. UNTREATED COATED (lbs.)	200 FEET: SHELL THICKNESS (INCHES)	WIRE † GAGE No. §	WIRE † SPACING (INCHES)	WEIGHT PER LIN. FT. UNTREATED COATED (lbs.)
4	1 1/16	8	2¼	5.8	1 1/16	8	1⅛	6.2
6	1⅛	6	2 7/16	8.7	1⅛	6	1 3/16	9.6
8	1⅛	6	2¼	11.2	1⅛	6	1⅛	12.4
10	1⅛	4	2¼	14.3	1⅛	4	1¼	15.9
12	1 3/16	4	2⅛	17.7	1 3/16	4	1⅛	20.4
14	1 3/16	4	2	21.0	1 3/16	2	1⅜	24.6
16	1¼	2	2¼	25.5	1¼	2	1 3/16	29.9
18	1¼	2	2 1/16	28.8	1¼	2	1 1/16	34.3
20	1 5/16	2	1⅞	33.5	1 5/16	2	15/16	40.5
24	1 5/16	2	1 9/16	41.4	1⅜	2	¾	53.6
	300 FEET				**400 FEET**			
4	1 1/16	8	¾	6.7	1 1/16	8	9/16	7.3
6	1⅛	6	13/16	10.3	1⅛	6	9/16	11.6
8	1⅛	6	¾	13.8	1⅛	6	9/16	15.1
10	1¼	4	⅞	19.1	1¼	4	⅝	21.2
12	1¼	4	¾	24.1	1¼	4	9/16	27.0
14	1¼	2	⅞	29.6	1¼	2	⅝	34.3
16	1 5/16	2	¾	36.6	1 5/16	2	9/16	41.7
18	1 5/16	2	11/16	41.9	1 5/16	2	½	48.7
20	1⅜	2	⅝	49.5	1⅜	2	7/16	58.3
24	1⅜	2	½	64.4	1⅜	1	7/16	74.4

§ American Steel & Wire Co.

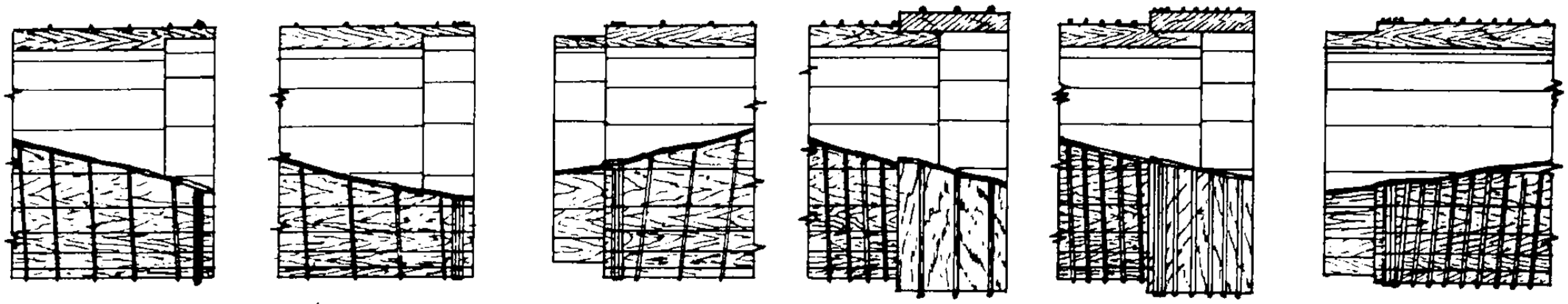
† Medium steel special pipe winding wire, heavily galvanized, ultimate tensile strength 58,000 to 68,000 p.s.i., allowable working stress = 15,000 p.s.i.
Pipe manufactured in lengths, 6 ft. to 20 ft.

UNTREATED COATED pipe is provided with exterior coating of asphaltum. Used where internal pressure is over 20 p.s.i. providing constant water saturation for preservation, and for domestic water lines where creosoted pipe may be objectionable.

CREOSOTED pipe is made from staves pressure treated to retain minimum of 8 lbs. creosote oil per cubic foot. Used for low pressure pipe lines.

Data furnished for Douglas Fir pipe by Federal Pipe & Tank Co., Seattle, Washington.
Wood stave pipe also made from hemlock, spruce, yellow pine, cypress and redwood.

WATER DISTRIBUTION-WOOD STAVE PIPE DETAILS

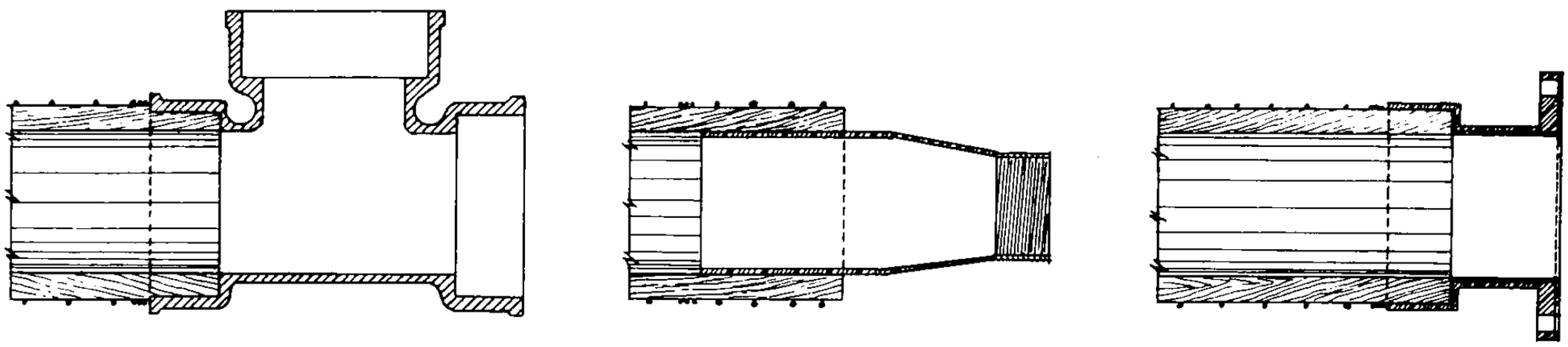


sizes 14" to 24" Female — sizes up to 12" Female — Male

INSERTED JOINTS (LOW PRESSURE)

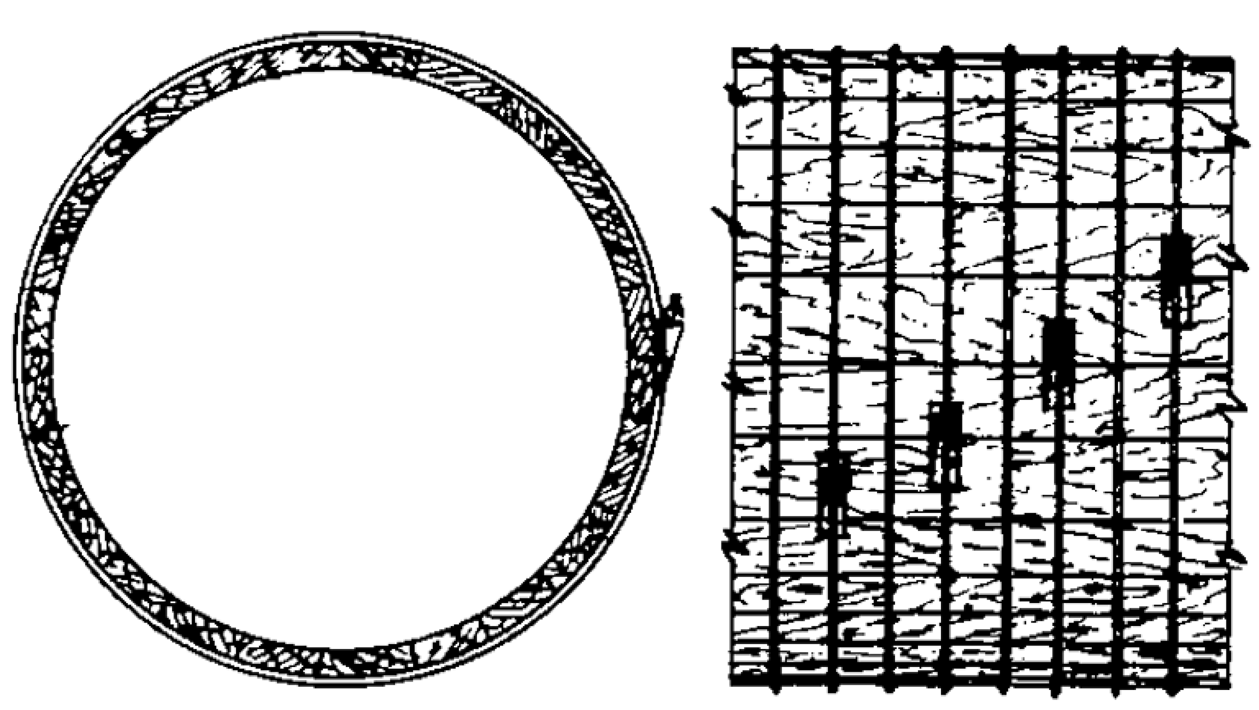
sizes 18" to 24" Female — sizes up to 16" Female — Male

COLLAR JOINTS (HIGH PRESSURE)

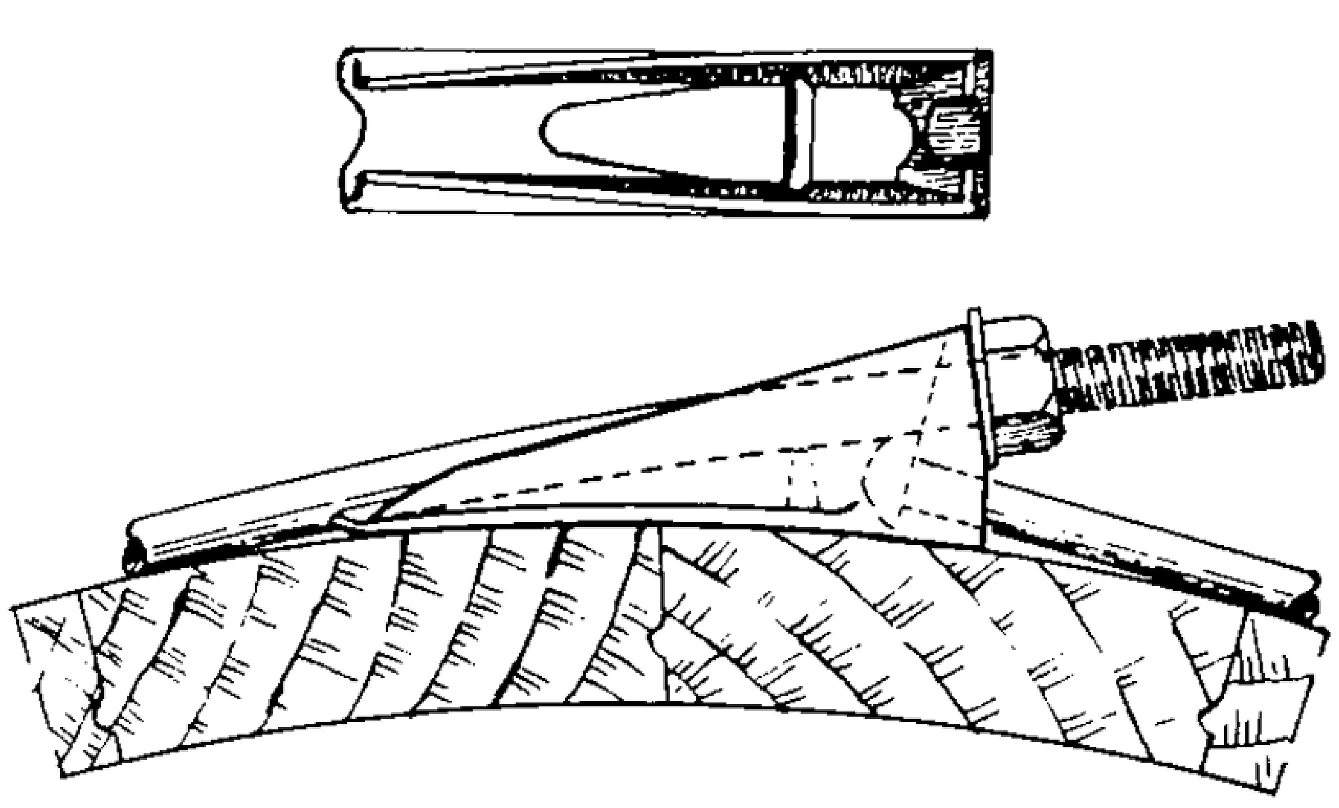


CAST IRON WOOD PIPE FITTING — **WELDED STEEL WOOD PIPE FITTING** — **HUBEND WELDED STEEL FITTING**

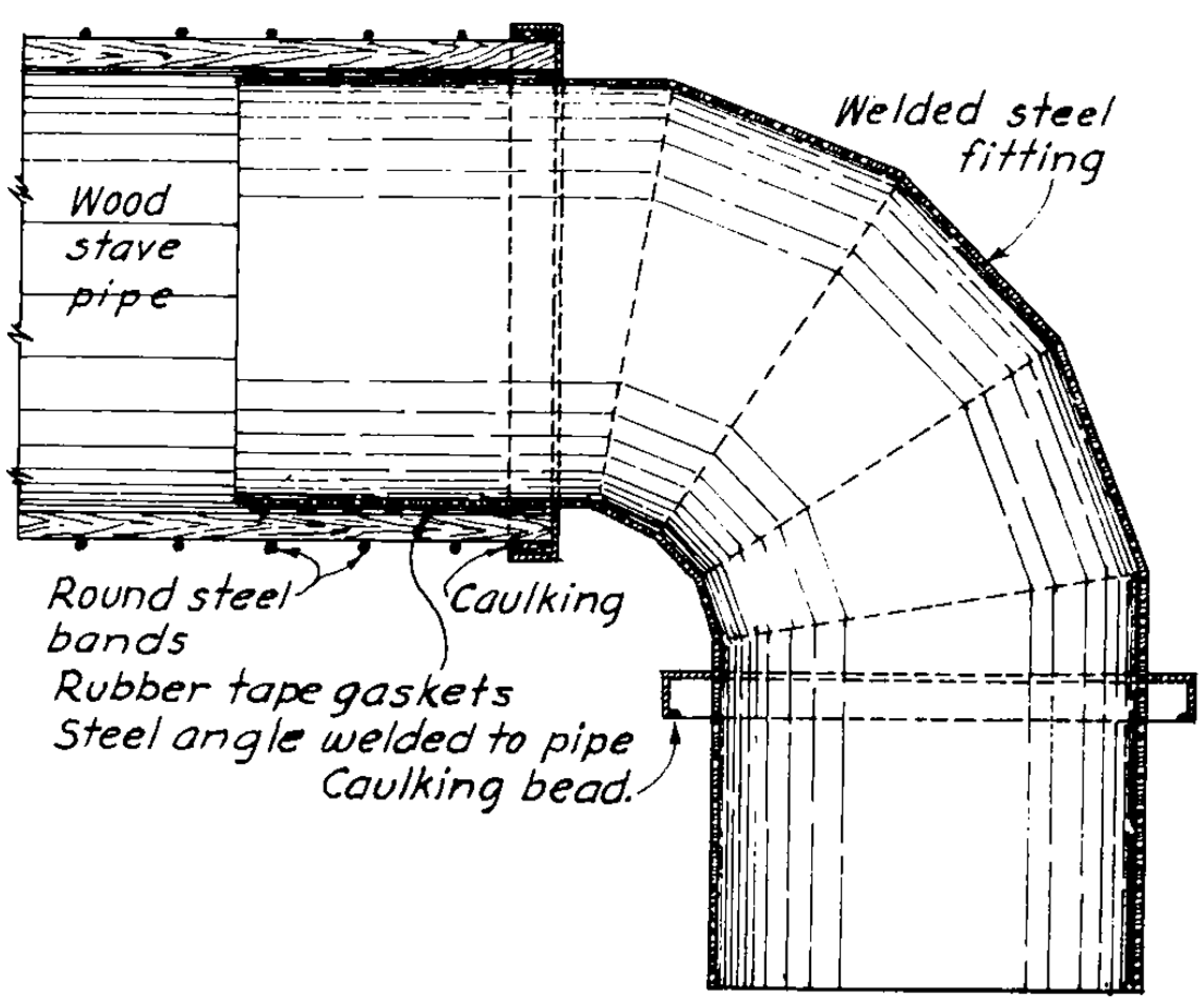
FIG. A- WIRE WOUND PIPE COUPLINGS AND FITTINGS.



CROSS SECTION — SIDE VIEW



DETAIL OF STAVE, STEEL BAND AND MALLEABLE IRON SHOE



WELDED STEEL BEND WITH CAULKING HUB

FIG. B- CONTINUOUS WOOD STAVE PIPE AND FITTINGS.

Details by Federal Pipe & Tank Co., Seattle, Wash.

WATER DISTRIBUTION - STEEL PIPE - 1

STEEL PIPE DESIGN: Table A below gives thickness of steel pipe recommended by Underwriters Laboratories, Inc. (sponsored by National Board of Fire Underwriters) unless experience in particular localities has shown that pipe with thinner walls has given satisfactory performance. Thickness computed from formula on Pg. 6-75 ; f_s = 7,200 lb. p.s.i for distribution mains ; f_s = 12,000 lb. p.s.i for supply lines ; 1/16" added for corrosion ; water hammer of ordinary intensity allowed for in table.

TABLE A - PERMISSIBLE MINIMUM WALL THICKNESSES & WEIGHTS PER FOOT.

PIPE DIAMETER,* INCHES	SUPPLY LINES & TRANSMISSION MAINS.								DISTRIBUTION MAINS.							
	100 psi. WORKING PRESS.		150 psi. WORKING PRESS.		200 psi. WORKING PRESS.		250 psi. WORKING PRESS.		100 psi. WORKING PRESS.		150 psi. WORKING PRESS.		200 psi. WORKING PRESS.		250 psi. WORKING PRESS.	
	THICKNESS DECIMAL	WEIGHT PER FT.	THICKNS DECIMAL	WT. PER FT.	THICKNS DECIMAL	WT. PER FT.	THICKNS DECIMAL	WT. PER FT.	THICKNS DECIMAL	WT. PER FT.	THICKNS DECIMAL	WT. PER FT.	THICKNS DECIMAL	WT. PER FT.	THICKNS DECIMAL	WT. PER FT.
2	0.141	3.36	0.141	3.36	0.141	3.36	0.141	3.36	0.141	3.36	0.141	3.36	0.141	3.36	0.141	3.36
4	.141	6.60	.141	6.60	.141	6.60	.141	6.60	.188	8.63	.188	8.63	.188	8.63	.188	8.63
6	.172	11.85	.172	11.85	.172	11.85	.172	11.85	.250	17.02	.250	17.02	.250	17.02	.250	17.02
8	.172	15.52	.172	15.52	.172	15.52	.172	15.52	.250	22.36	.250	22.36	.250	22.36	.250	22.36
10	.188	21.15	.188	21.15	.188	21.15	.188	21.15	.250	28.03	.250	28.03	.250	28.03	.250	28.03
12	.188	25.15	.188	25.15	.188	25.15	.188	25.15	.250	33.37	.250	33.37	.250	33.37	.281	37.45
14	.188	27.65	.188	27.65	.188	27.65	.218	32.09	.250	36.71	.250	36.71	.281	41.20	.313	45.68
16	.188	31.66	.188	31.66	.218	36.75	.250	42.05	.250	42.05	.250	42.05	.313	52.35	.344	57.52
18	.188	35.67	.188	35.67	.218	41.40	.250	47.39	.250	47.39	.250	47.39	.313	59.03	.375	70.58
20	.188	39.67	.188	39.67	.250	52.73	.281	59.23	.250	52.73	.281	59.23	.344	72.22	.438	91.40
22	.188	43.68	.218	50.72	.250	58.07	.313	72.38	.250	58.07	.313	72.38	.375	86.60	.500	114.81
24	.188	47.68	.218	55.37	.281	71.24	.313	79.05	.250	63.41	.313	79.05	.438	110.09	.500	125.49
26	.188	51.69	.250	68.75	.281	77.25	.344	94.26	.250	68.75	.344	94.26	.438	119.44	.563	152.95
28	.188	55.69	.250	74.09	.313	92.40	.375	110.63	.313	92.40	.375	110.63	.500	146.85	.563	164.98
30	.188	59.70	.250	79.43	.313	99.08	.375	118.64	.313	99.08	.375	118.64	.500	157.53	.750	234.30
32	.218	74.00	.281	95.19	.344	116.30	.438	147.65	.313	105.93	.438	147.65	.563	189.03	.750	250.32
34	.218	78.65	.281	101.20	.375	134.67	.438	157.00	.313	112.61	.438	157.00	.563	201.06	.750	266.34
36	.250	95.45	.313	119.10	.375	142.68	.438	166.16	.313	119.10	.438	166.16	.563	213.08	.750	282.36
42	.250	111.47	.344	153.04	.438	194.20	.500	221.61	.375	166.71	.500	221.61	.750	330.41	1.000	437.89
48	.313	159.15	.375	190.74	.500	253.65	.563	285.24	.438	222.23	.563	285.24	.750	378.48	1.000	501.97
54	.313	179.18	.438	250.27	.563	321.31	.625	356.28	.438	250.27	.625	356.28	.875	496.45	1.000	566.05
60	.313	199.21	.438	278.30	.563	357.07	.750	474.59	.500	317.73	.750	474.59	1.000	630.13		
66	.375	262.83	.500	349.77	.625	436.38	.750	522.66	.500	349.77	.750	522.66	1.000	694.21		
72	.375	286.86	.563	429.16	.750	570.72	.875	664.67	.563	429.16	.875	664.67				
84	.438	390.45	.625	556.53	.875	776.82	1.000	886.46	.625	556.53	1.000	886.46				
96	.500	509.97	.750	762.95	.875	888.96	1.063	1077.82	.750	762.95						

*Diam. 2" through 12" are nominal, see Table B below for outside diam. Diameters 14" and larger are outside diam.
Pipe for working pressures less than 100 psi shall have the same wall thickness as pipe for 100 psi.
Weights per foot are unlined and uncoated pipe.

TABLE B - STEEL PIPE A.S.T.M. - A53-44 - WEIGHTS & DIMENSIONS.

PIPE DIAMETER NOMINAL SIZES, INCHES	OUTSIDE DIAMETER INCHES	NUMBER OF THREADS PER INCH	"STANDARD WEIGHT" PIPE				"EXTRA STRONG" PIPE				DOUBLE EXTRA STRONG" PIPE	
			SCHEDULE 30		SCHEDULE 40		SCHEDULE 60		SCHEDULE 80			
			THICKNESS IN INCHES	WT. OF PIPE lb. PER FT. THREADED & WITH COUPLINGS	THICKNS IN INCHES	WT. OF PIPE lb. PER FT. THREADED & WITH COUPLINGS	THICKNS. IN INCHES	WEIGHT OF PIPE lb. PER FT. PLAIN ENDS.	THICKNS. IN INCHES	WEIGHT OF PIPE lb. PER FT. PLAIN ENDS.	THICKNS. IN INCHES	WEIGHT OF PIPE lb. PER FT. PLAIN ENDS.
2	2.375	11 1/2			0.154	3.68			0.218	5.02	0.436	9.03
4	4.500	8			0.237	10.89			0.337	14.98	0.674	27.54
6	6.625	8			0.280	19.18			0.432	28.57	0.864	53.16
8	8.625	8	0.277	25.00	0.322	28.81			0.500	43.39	0.875	72.42
10	10.750	8	0.307	35.00	0.365	41.13	0.500	54.74				
12	12.750	8	0.330	45.00	0.375	50.71	0.500	65.41				

Sizes larger than 12" are specified by their outside diameter, O.D., & thickness. These larger sizes are furnished with plain ends, unless otherwise specified. The weights for O.D. pipe are given by manufacturers' published standards although it is possible to calculate the theoretical weights for any given size & wall thickness on the basis of 1 cu. in. of steel weighing 0.2833 lb.
Table does not give complete list of sizes less than 6".

WATER DISTRIBUTION - STEEL PIPE-2

TABLE A - STEEL PIPE DATA.††

OUTSIDE DIAMETER IN INCHES	U.S.S. GAGE	WEIGHT PER FT. POUNDS ASPHALT DIPPED	SAFE WORKING PRESSURE* IN P.S.I.	APPROXIMATE COLLAPSING PRESSURE†
6"	16	4.3	250	60
	14	5.3	312	120
	12	7.3	438	338
7"	16	5.2	214	37
	14	5.9	268	74
	12	8.3	375	209
8"	16	5.7	187	25
	14	7.4	234	49
	12	9.7	328	140
	10	12.3	422	301
	7	16.2	562	744
8⅝	16	6.2	174	20
	14	7.6	217	39
	12	11.1	304	110
	10	13.9	391	237
	7	18.0	522	585
10"	14	9.1	187	25
	12	12.2	263	70
	10	15.5	337	152
	7	20.3	450	371
10¾	14	9.5	174	20
	12	13.8	244	56
	10	17.3	314	120
	7	22.6	419	296
	3	29.4	558	726
12"	14	11.1	156	14
	12	14.6	219	40
	10	18.5	281	86
	7	24.5	375	209
	3	32.9	500	511
12¾	14	11.4	147	12
	12	16.4	206	33
	10	20.6	265	72
	7	26.8	353	172
	3	35.0	471	424
14"	14	12.7	134	9
	12	17.1	188	25
	10	21.7	241	53
	7	28.6	321	131
	3	38.5	429	317
16"	14	14.7	117	6
	12	19.6	164	17
	10	24.9	211	36
	7	32.7	281	86
	3	44.1	375	209
18"	14	16.7	104	4
	12	22.0	146	12
	10	28.0	187	25
	7	36.9	250	60
	3	49.7	333	146
	0	61.4	417	292
20"	14	18.1	94	3
	12	24.5	131	8
	10	31.1	169	18
	7	41.0	225	44
	3	55.4	300	105
	0	68.3	375	209
22"	14	19.8	85	2
	12	27.0	119	6
	10	34.3	153	14
	7	45.1	205	33
	3	60.9	273	78
	0	75.3	341	156
	000	89.5	409	273
	00000	103.7	477	443
24"	14	21.8	78	1.8
	12	29.5	109	5
	10	37.4	141	10
	7	49.3	187	25
	3	66.6	250	60
	0	82.3	312	120
	000	97.8	375	209
30"	14	27.2	62	0.9
	12	35.5	88	2.5
	10	46.6	112	5
	7	62.2	150	13
	3	94.0	200	30
	0	103.1	250	60
	000	122.7	300	105
	00000	142.1	350	169
	0000000	161.5	400	254
36"	14	32.3	52	0.5
	12	42.5	73	1.4
	10	55.8	94	3
	7	74.5	125	7
	3	113.0	167	17
	0	123.9	208	34
	000	147.5	250	60
	00000	171.0	292	98
	0000000	194.4	333	146
42"	12	49.5	63	0.9
	10	65.1	80	3
	7	87.0	107	5
	3	131.0	143	11
	0	143.6	179	22
	000	170.7	214	38
	00000	197.7	250	60
	0000000	225.8	286	91
48"	12	56.5	55	0.6
	10	74.3	70	1.3
	7	99.2	94	3
	3	133.2	125	7
	0	164.6	156	14
	000	195.6	187	25
	00000	226.6	219	40
	0000000	257.4	250	60
54"	12	65.0	49	0.4
	10	84.0	62	0.9
	7	111.5	83	2.1
	3	160.6	111	5
	0	185.4	139	10
	000	220.5	167	17
	00000	255.4	194	28
	0000000	290.2	222	42
60"	10	93.2	56	0.6
	7	124.4	75	1.5
	3	198.0	100	3.7
	0	206.2	125	7
	000	245.4	150	13
	00000	284.2	175	20
	0000000	323.0	200	30
66"	10	102.4	51	0.5
	7	136.7	68	1.2
	3	207.0	91	2.8
	0	227.0	114	5
	000	270.2	136	10
	00000	313.1	159	15
	0000000	355.9	182	23
72"	10	111.7	47	0.4
	7	149.2	62	0.9
	3	225.0	83	2.1
	0	246.7	104	4.2
	000	293.4	125	7
	00000	339.8	146	12
	0000000	387.3	167	17

TABLE B - U.S. STANDARD GAGES FOR SHEET AND PLATE STEEL.††

Gage Number	0000000	00000	000	0	3	7	10	12	14	16
Approx. Thickness in Inches.	1/2	7/16	3/8	5/16	1/4	3/16	9/64	7/64	5/64	1/16

*Safe working pressure based on fiber stress of 12,000 p.s.i. - No allowance made for corrosion or water hammer. See Table A, page 6-73 for recommendations sponsored by the National Board of Fire Underwriters.
†Collapsing pressures are in p.s.i., computed by Carman Formula. ††From Handbook of Water Control by the California Corrugated Culvert Co.

WATER DISTRIBUTION — STEEL PIPE-3

TABLE A - MAXIMUM HEIGHT FOR BACKFILLING IN FEET FOR WELDED STEEL PIPE.
(EITHER TRENCH OR EMBANKMENT CONDITION)

DIAMETER	14 GAGE.	12 GAGE	10 GAGE	7 GAGE	3 GAGE
4"	138	298			
5"	92	198			
6"	66	142			
7"	50	107			
8"	39	84	148	293	
9"	31	68	119	236	
10"	26	56	98	195	
11"	22	47	82	163	
12"	19	40	70	139	178
14"		30	53	105	134
16"		24	42	82	105
18"		19	33	66	85
20"			28	55	70
22			23	46	58
24"			20	39	50
30"				26	33
36"				19	24
42"					18
48"					14
54"					11
60"					9
66"					8
72"					7

Maximum allowable deflection = 2% of diameter. Table based on bottom and side support obtained by hand tamping.

TABLE B - SAFE SPANS BETWEEN SUPPORTS IN FEET FOR WELDED STEEL PIPE ABOVE GROUND.

DIAMETER	16 GA.	14 GA.	12 GA.	10 GA.	7 GA.	3 GA.
4"	15.5	17.5	18.5	21	22	23.5
5"	16.5	17.5	19.5	22	23.5	25
6"	16.5	18	20.5	22.5	24	26.5
7"	17.5	18.5	21	23	25	27.5
8"	17.5	18.5	22	23.5	26.5	28.5
9"	17.5	19	22.5	24	27	29.5
10"	18	19.5	22.5	24.5	27.5	30
12"	18	19.5	23	25.5	28	31
14"	18.5	20.5	23.5	26.5	29	32
16"	18.5	20.5	23.5	26.5	29.5	33
18"		21	24	27	30	33.5
20"		21	24	27.5	30.5	34
22"			24.5	27.5	30.5	34.5
24"			24.5	28	31	35
30"				28	32	35.5
36"					32.5	36.
42"					33	37
48"						37

Based on strength of pipe as beam and resistance to crushing at supports. For spans below heavy line, reinforcement at supports is recommended to prevent crushing.

DESIGN OF WELDED STEEL PIPE

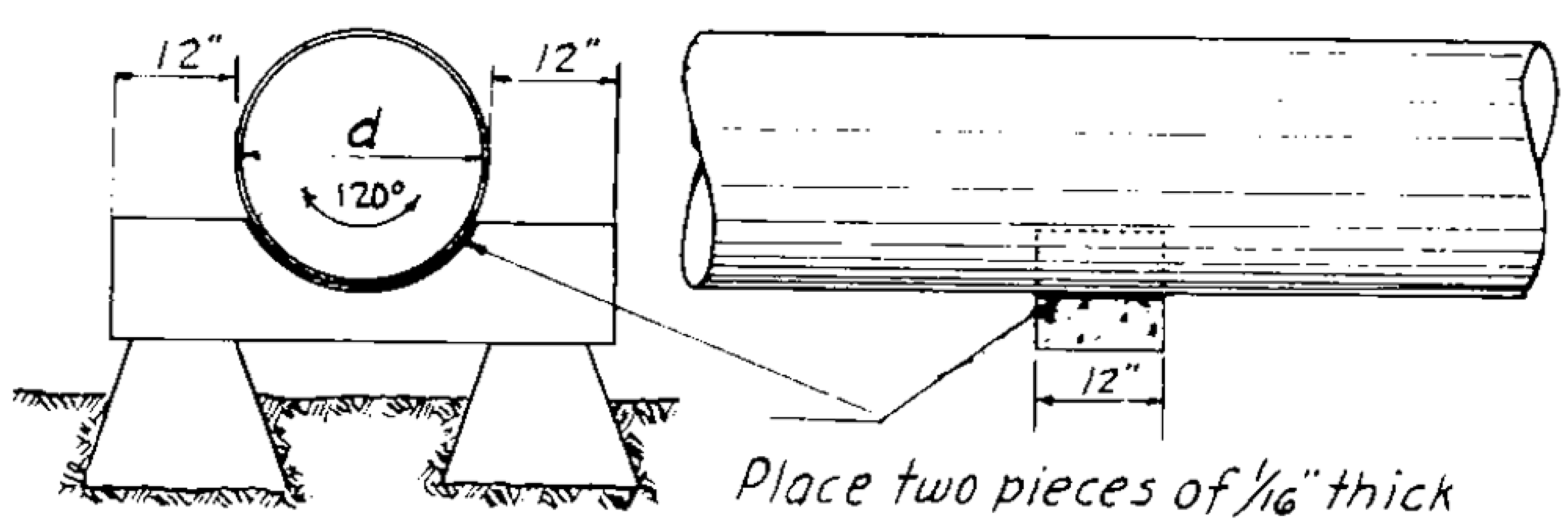
Internal Pressure Formula:- $t = \frac{p \times d}{2 f_s}$

t = Thickness of pipe in inches.
P = Internal water pressure in p.s.i
d = Outside diameter of pipe in inches.
f_s = Safe working stress in material in p.s.i.
NOTE: Allowance to be made in P for possible excess stress caused by water hammer. See Table C - page 6·68.

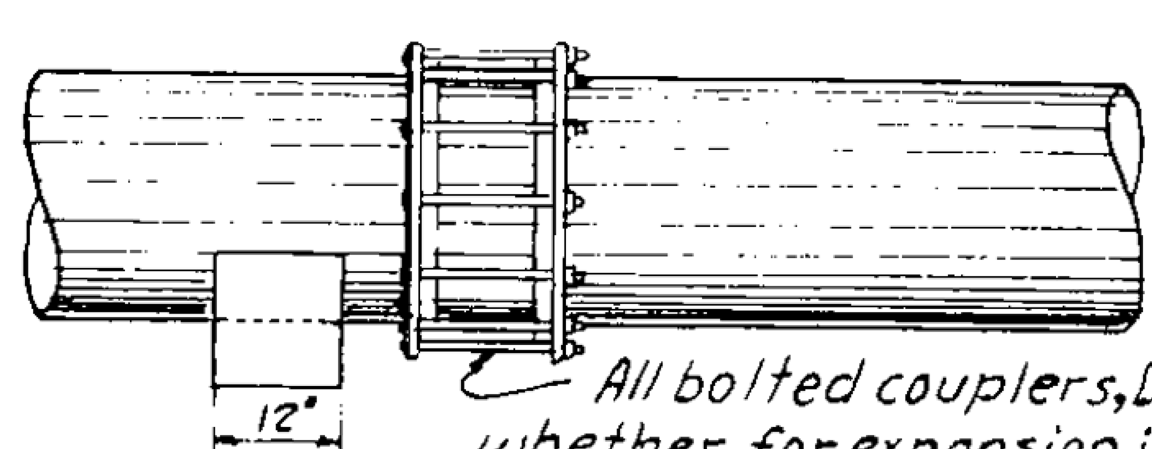
EXPANSION IN WELDED STEEL PIPES.

Temperature Stress Formula: $S = T \times E \times n$.

S = Temperature Stress in p.s.i.
T = Range in temperature in degrees F.
E = Modulus of elasticity = 30,000,000.
n = Coefficient of expansion = 0.0000065.



Place two pieces of 1/16" thick sheet packing - One fastened to pipe, the other to saddle. Place thin layer of Graphite Grease between.



All bolted couplers, Dayton or Dresser whether for expansion joints or regular joints, are to be placed as closely to supports as possible.

FIG. C- SADDLE SUPPORT FOR WELDED STEEL PIPE.

EXPANSION JOINTS such as Dayton or Dresser couplings (see Fig. D-p. 6-69) with long middle rings to be provided for pipes above ground where S > safe working stress of material. Seldom required where continuous flow of water is maintained or where pipe line is very sinuous. Temperature stress can be neglected in buried pipe lines.
THRUST AT BENDS in pipe due to internal pressure - see Table p. 6-77.

Data from Handbook of Water Control, by the California Corrugated Culvert Co.

WATER DISTRIBUTION - PIPE CURVATURE

TABLE A - ALLOWABLE CURVATURE OF PIPE WITH ORDINARY JOINTS.

PIPE SIZE (INCHES)	CAST IRON PIPE BELL & SPIGOT: MAXIMUM DEFLECTION IN ONE JOINT	CAST IRON PIPE BELL & SPIGOT: DEFLECTION IN 12 FOOT LENGTH (INCHES)	CAST IRON PIPE BELL & SPIGOT: RADIUS OF CURVE (FEET)	STEEL PIPE - FIELD WELDED* (SWAGED ENDS-1/4 MIN. LAP): MAXIMUM DEFLECTION IN ONE JOINT	STEEL PIPE: RADIUS OF CURVE (IN FEET) 20' PIPE LENGTH	STEEL PIPE: RADIUS OF CURVE (IN FEET) 30' PIPE LENGTH	STEEL PIPE: RADIUS OF CURVE (IN FEET) 40' PIPE LENGTH	CEMENT-ASBESTOS PIPE TRANSITE - SIMPLEX COUPLINGS, 0 TO 25 P.S.I.: MAXIMUM DEFLECTION IN ONE JOINT	0 TO 25 P.S.I.: RADIUS OF CURVE 10' LENGTHS (FEET)	100 TO 150 P.S.I.: MAXIMUM DEFLECTION IN ONE JOINT	100 TO 150 P.S.I.: RADIUS OF CURVE 10' LENGTHS (FEET)
4	4°-00'	10.00	[illegible]	[illegible]8°-15'	63	95	126	17°	33.8	5°	114
6	3°-30'	8.80	96	[illegible]2°-00'	96	143	192	12°	47.8	5°	114
8	3°-[illegible]4'	8.12	212	9°-00'	128	191	255	9°	63.5	5°	114
[illegible]	[illegible]	[illegible].83	226	[illegible]°-15'	158	237	316	7°	81.8	5°	114
[illegible]	3°-[illegible]	7.50	230	6°-00'	191	287	382	6°	95.3	5°	114
[illegible]6	2°-[illegible]4	6.80	260	4°-30'	255	382	509	6°	95.3	5°	114
[illegible]8	2°-26	6.10	283	4°-00'	287	430	574	5°	114	5°	114
2[illegible]	2°-09	5.40	320	3°-30'	328	492	656	5°	114	5°	114
24	[illegible]°-47	4.50	390	3°-00'	382	572	764	4°	143	4°	143
30	[illegible]°-26'	3.60	480	2°-30'	459	688	917	3°	191	3°	191
36	[illegible]°-[illegible]2	3.00	570	2°-00'	575	863	1150	3°	191	3°	191

TABLE B - DEFLECTION ANGLES OBTAINABLE FOR VICTAULIC COUPLINGS - STEEL PIPE.*

PIPE SIZE (INCHES)	4	6	8	10	12	14	16	18	20	24
MAXIMUM DEFLECTION IN ONE COUPLING	3°	2°-[illegible]0'	1°-40'	1°-20'	1°-07'	1°-02'	0°-54'	0°-48'	0°-43'	0°-36'

DRESSER COUPLINGS (See Fig. D-p. 6-63) *Deflection angle of 3° to 4° obtainable in one coupling, any pipe size.*

CENTURY ASBESTOS CEMENT PIPE WITH CENTURY FLEXIBLE COUPLINGS: *Deflection angle of 4° to 6° obtainable in one coupling, any pipe size.*

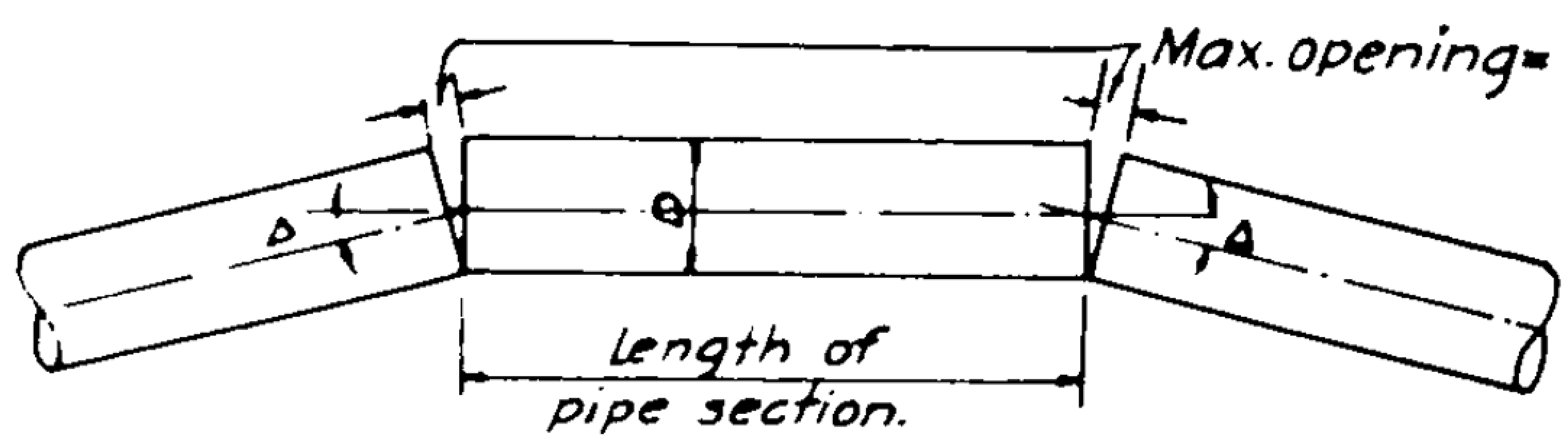
BALL & SOCKET JOINT CAST IRON PIPE: *Approximate maximum deflection at one joint - 15°*

TABLE C - CONTINUOUS WOOD STAVE PIPE.**

Maximum curvature under average construction conditions.

PIPE DIAM. (FEET)	2	2.5	3	3.5	4	5	6	7	8	10	12
RADIUS (FEET)	[illegible]	125	150	175	205	260	310	370	425	535	630

Section to be curved is built on tangent with moderately tightened bands, then forced into curve and bands tightened.



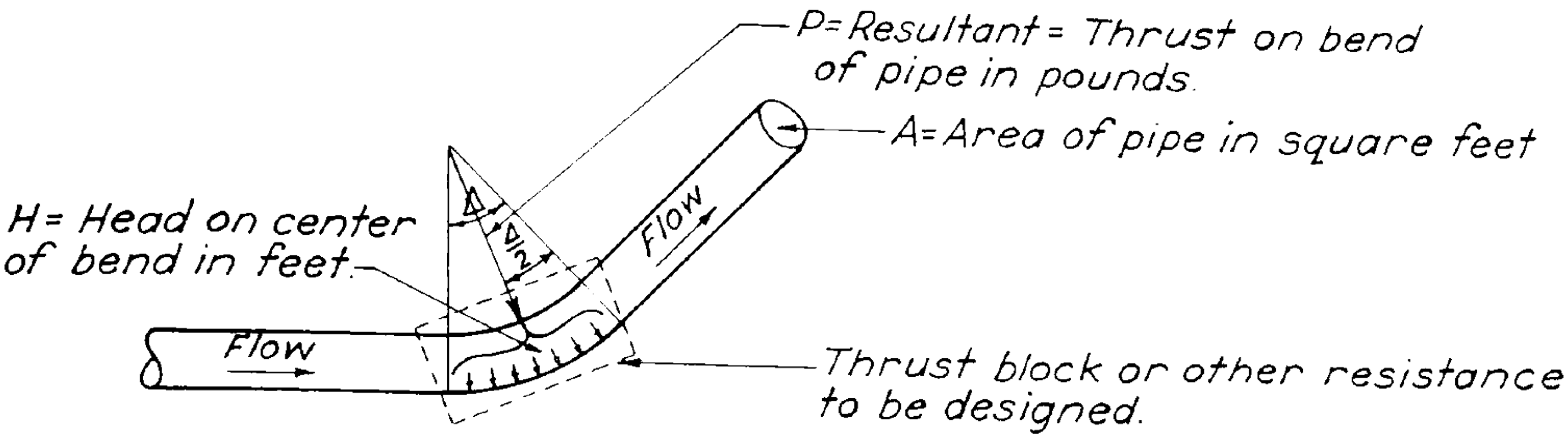
Max. opening = { 3/8" for heads up to 250 feet. / 1/4" " " 250 to 400 feet. / 1/8" " " over 400 feet. }

$$\text{Tangent } \Delta = \frac{\text{Opening}}{D}$$

FIG. D - CURVATURE IN WIRE-WOUND WOOD STAVE PIPE.

* Data from Handbook of Water Control by the California Corrugated Culvert Co.
** Data from Federal Pipe & Tank Co. Seattle, Wash.

WATER DISTRIBUTION - REACTIONS AT BENDS

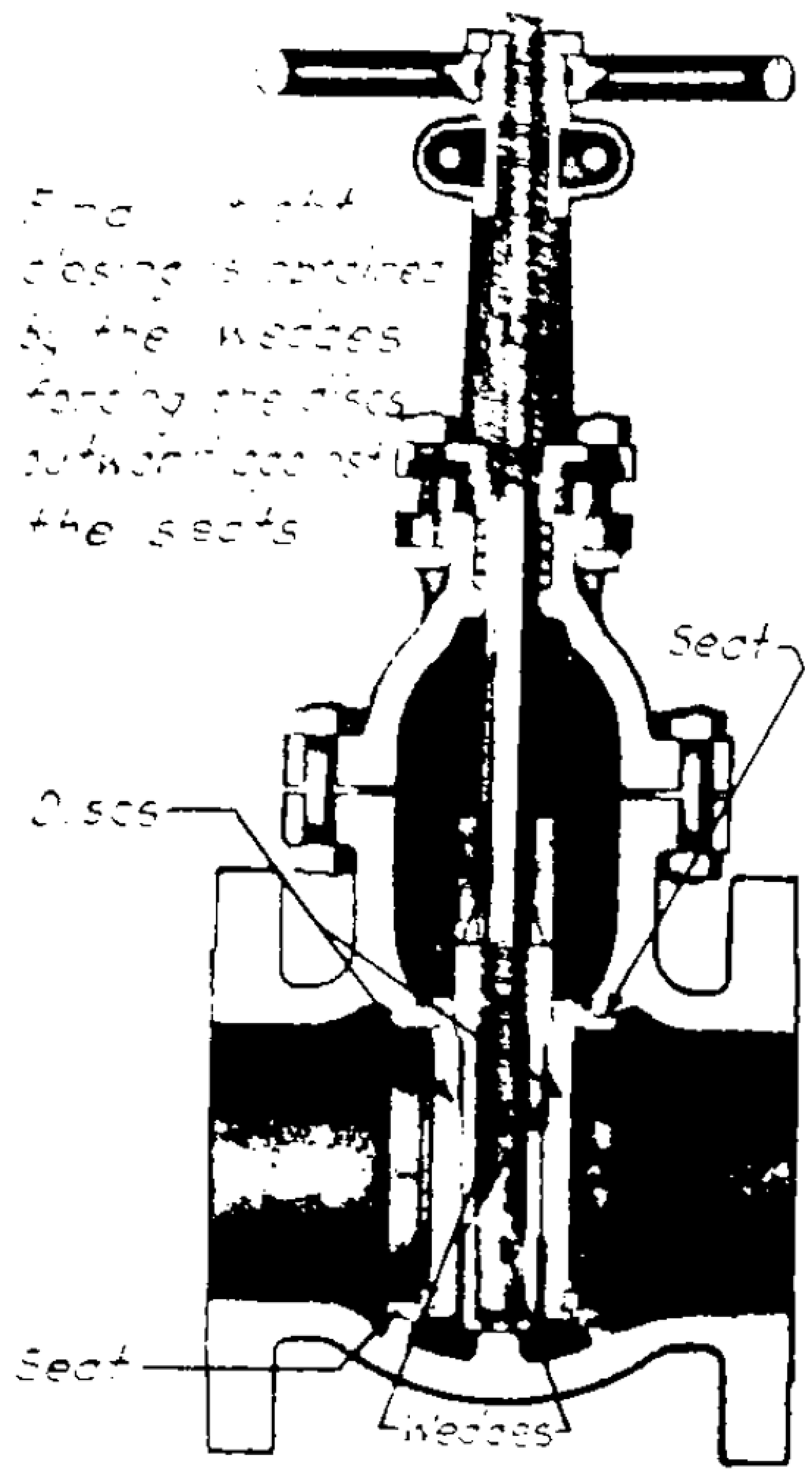


$$P = 2 \times 62.5\, HA \sin \tfrac{1}{2} \Delta$$

Values given in table = thrust on pipe in pounds.

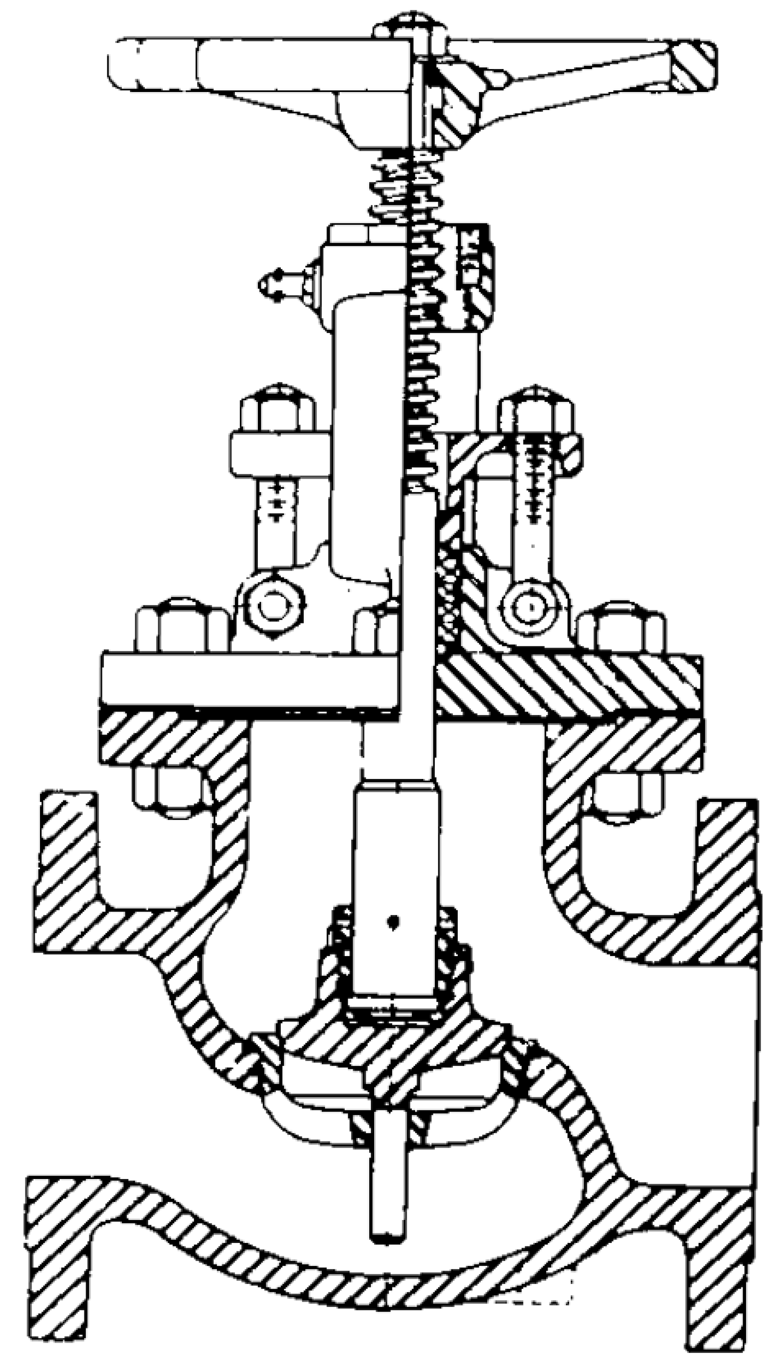
INSIDE DIAM. OF PIPE IN INCHES	90° BEND			45° BEND			$22\frac{1}{2}$° BEND			$11\frac{1}{4}$° BEND		
	H=100'	H=200'	H=300'	H=100'	H=200'	H=300'	H=100'	H=200'	H=300'	H=100'	H=200'	H=300'
2	193	386	579	104	208	312	53	106	159	27	54	81
3	430	860	1,290	235	470	705	120	240	360	61	122	183
4	770	1,540	2,310	418	836	1,250	213	426	639	109	218	327
6	1,730	3,460	5,190	940	1,880	2,820	480	960	1,440	246	492	738
8	3,080	6,160	9,240	1,670	3,340	5,010	850	1,700	2,550	437	874	1,310
10	4,820	9,640	14,500	2,610	5,220	7,830	1,330	2,660	3,990	682	1,360	2,050
12	6,940	13,900	20,800	3,760	7,520	11,300	1,910	3,820	5,730	983	1,970	2,950
14	9,450	18,900	28,400	5,120	10,200	15,400	2,610	5,220	7,830	1,340	2,680	4,020
16	12,300	24,700	37,000	6,680	13,400	20,000	3,400	6,800	10,200	1,750	3,500	5,250
18	15,600	31,200	46,800	8,450	16,900	25,400	4,300	8,600	12,900	2,210	4,420	6,630
20	19,300	38,600	57,900	10,400	20,800	31,200	5,330	10,700	16,000	2,730	5,460	8,190
24	27,800	55,600	83,400	15,000	30,000	45,000	7,650	15,300	23,000	3,930	7,860	11,800
30	43,400	86,800	130,000	23,500	47,000	71,000	12,000	24,000	36,000	6,140	12,300	18,400
36	62,500	125,000	188,000	33,800	67,600	101,000	17,200	34,400	51,600	8,850	17,700	26,600
42	85,000	170,000	255,000	46,000	92,000	138,000	23,500	47,000	70,500	12,000	24,000	36,000
48	111,000	222,000	333,000	60,200	120,000	181,000	30,600	61,200	91,800	15,700	31,400	47,100
54	140,000	280,000	420,000	76,000	152,000	228,000	38,800	77,600	116,000	19,900	39,800	59,700
60	173,000	346,000	519,000	94,000	188,000	282,000	48,000	96,000	144,000	24,600	49,200	73,800
66	210,000	420,000	630,000	114,000	228,000	342,000	58,000	116,000	174,000	29,700	59,400	89,100
72	243,000	486,000	729,000	132,000	264,000	396,000	67,000	134,000	201,000	34,400	68,800	103,000

WATER DISTRIBUTION - VALVES-1



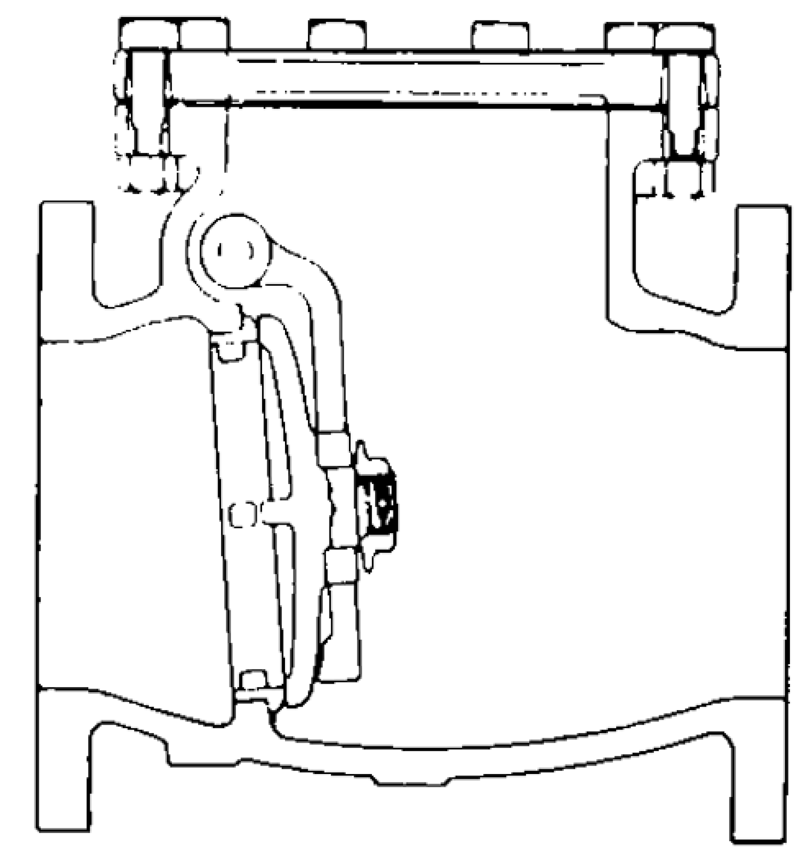
GATE VALVE *

<u>LOCATION</u> Any place in pipe.
<u>USE</u> - Most common type. Use from 4" dia. and larger.
<u>TYPES</u> - Double disc parallel seat (illustrated) used in waterworks practice. Solid wedge (most durable). Split-wedge (used in bronze valves to control light volatile fluids). Double disc taper seat (used in iron valves to control light volatile fluids).



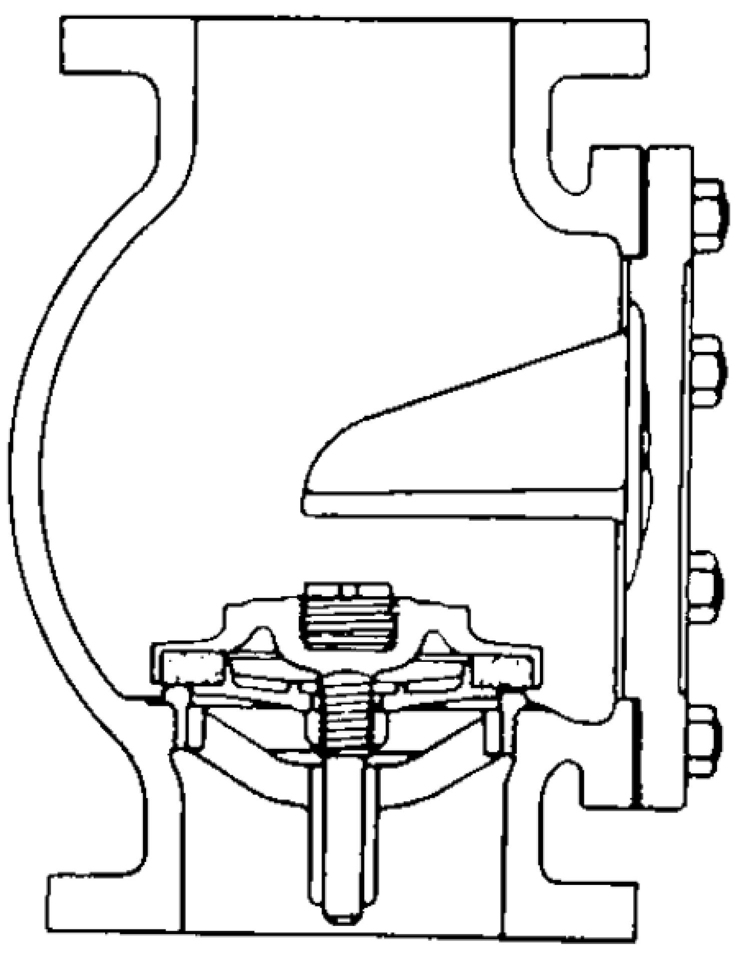
GLOBE VALVE **

<u>LOCATION</u> - Any place in pipe.
<u>USE</u> - To control rate of flow of fluids, where operation of valve is frequent.
<u>NOTES</u> - If inlet and outlet ends are placed at right angles to each other, valve is called an angle valve. Parts are easily replaced.



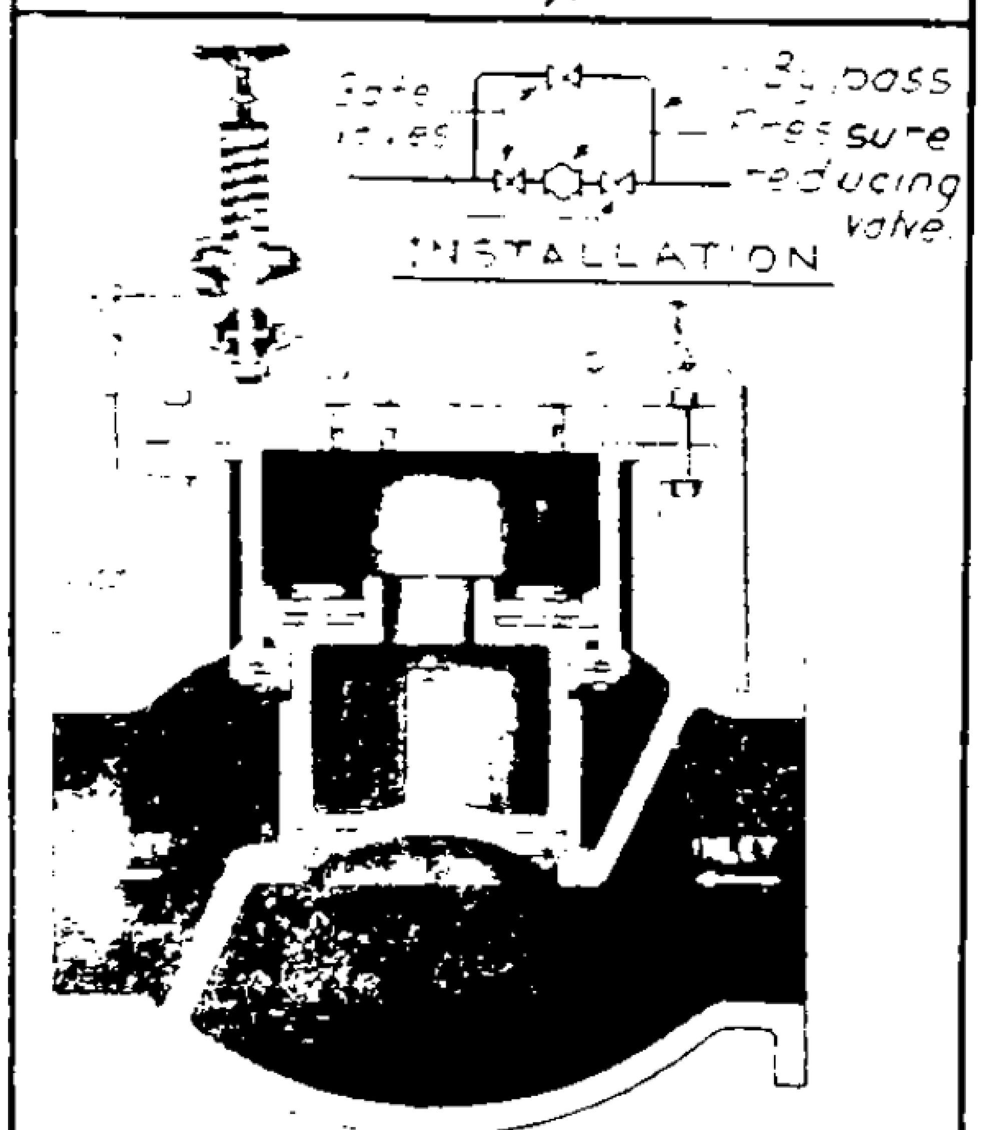
<u>LOCATION</u> - Any place in horizontal pipe.
<u>USE</u> - To permit fluid to flow in only one direction.
<u>NOTES</u> - Swing check valve has comparatively the least obstruction to flow of all check valves. Valve should always be set horizontally.
<u>OTHER TYPES</u> - Backwater valve. Automatic flap gate. Automatic tide gate.

SWING CHECK VALVE ***



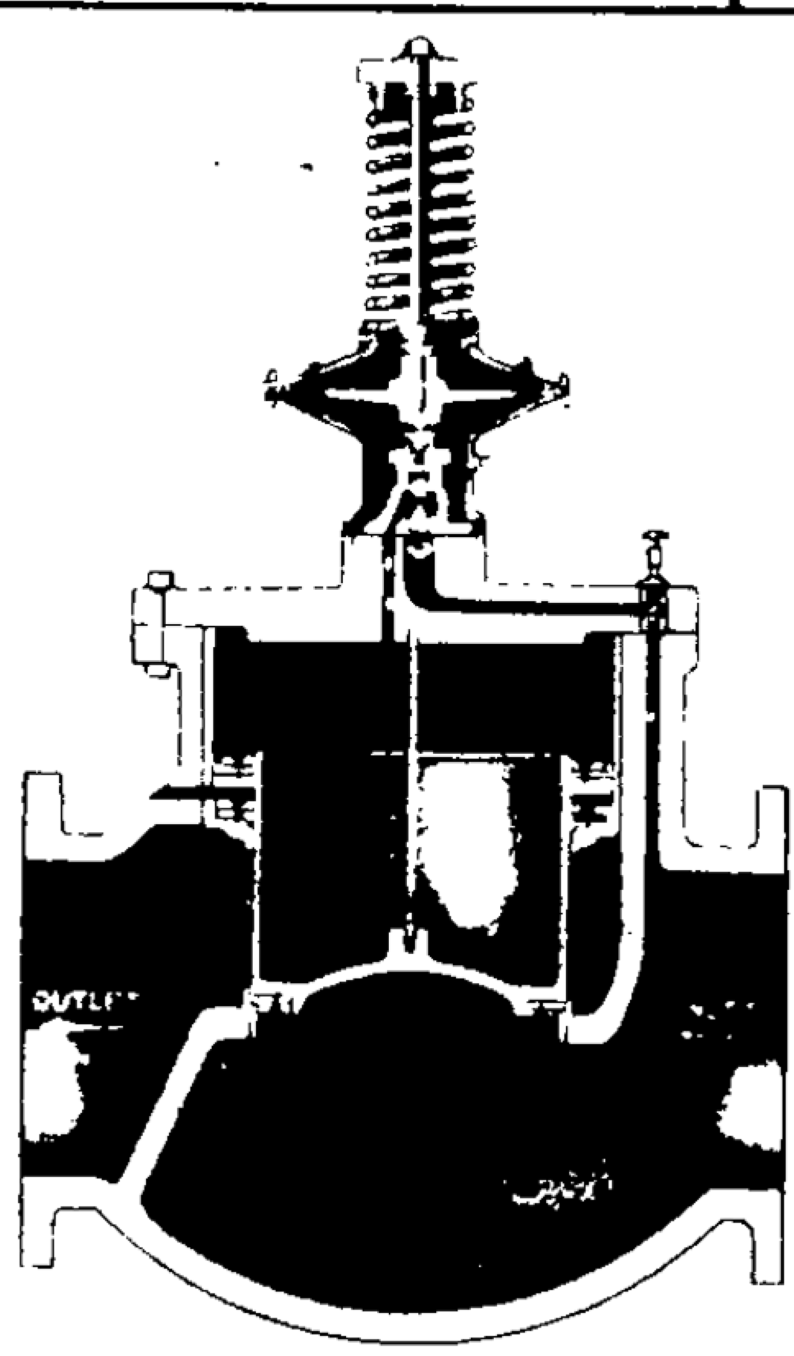
<u>LOCATION</u> - Any place in pipe.
<u>USE</u> - Lift check valve usually has most positive closure.
<u>TYPES</u> - Vertical (illus.) (inlet end on bottom and outlet end on top). Horizontal (inlet and outlet ends set in horizontal plane). Angle (inlet end on bottom and outlet end on side). Foot valve (vertical lift check with screen).
<u>NOTE</u> - Never use these valves at pressures and temperatures exceeding their maximum ratings.

LIFT CHECK VALVE ***



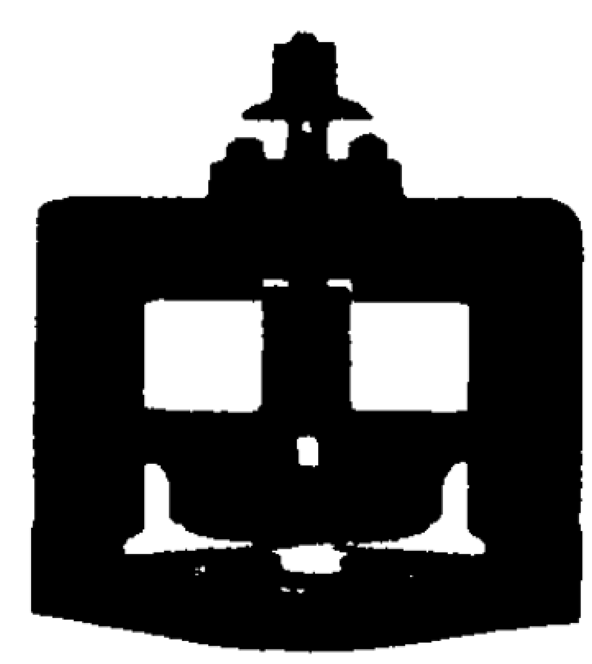
WATER PRESSURE REDUCING VALVE †

<u>LOCATION</u> - Any place in pipe.
<u>USE</u> - To maintain constant downstream pressure against higher inlet head



ALTITUDE CONTROL VALVE †

<u>LOCATION</u> - In inlet pipes to distribution reservoir elevated tanks and stand pipes.
<u>USE</u> - To stop flow when water in tank reaches a preset level and let water in again when level goes down.
<u>TYPES</u> - Single acting (illustrated) (allows flow only into reservoir). See installation, Page 6-11-Fig. A. Double acting (allows flow bothways installed same as pressure reducing valve)



<u>LOCATION</u> - Bottom of sumps, settling basins, channelways, etc.
<u>USE</u> - To drain or blow off.

PLUG DRAIN VALVE ††

AUTOMATIC FLAP GATE †††

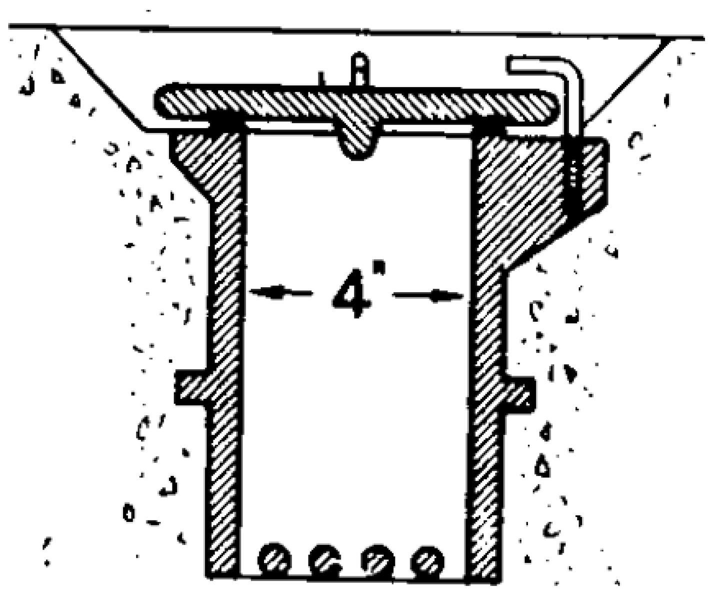
<u>LOCATION</u> - End of pipe lines.
<u>USE</u> - See swing check valve, above.

* From Crane Co. ** From Ludlow Valve Mfg. Co. *** From Jenkins Bros.
† From Golden-Anderson Valve Specialty Co. †† From Eddy Valve Co.
††† From Hardesty Division, Armco Drainage and Metal Products, Inc.

WATER DISTRIBUTION - VALVES -2

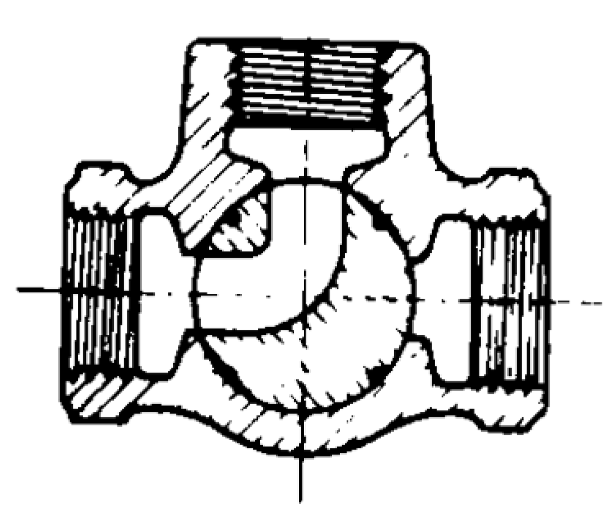
SHEAR GATE *

LOCATION - At ends of pipe line.
USE - To control discharge at low pressures.



PRESSURE RELIEF VALVE ***

LOCATION - In the bottom of concrete tanks.
USE - To prevent tank from floating when it is empty and there is excessive water pressure under and around the tank.

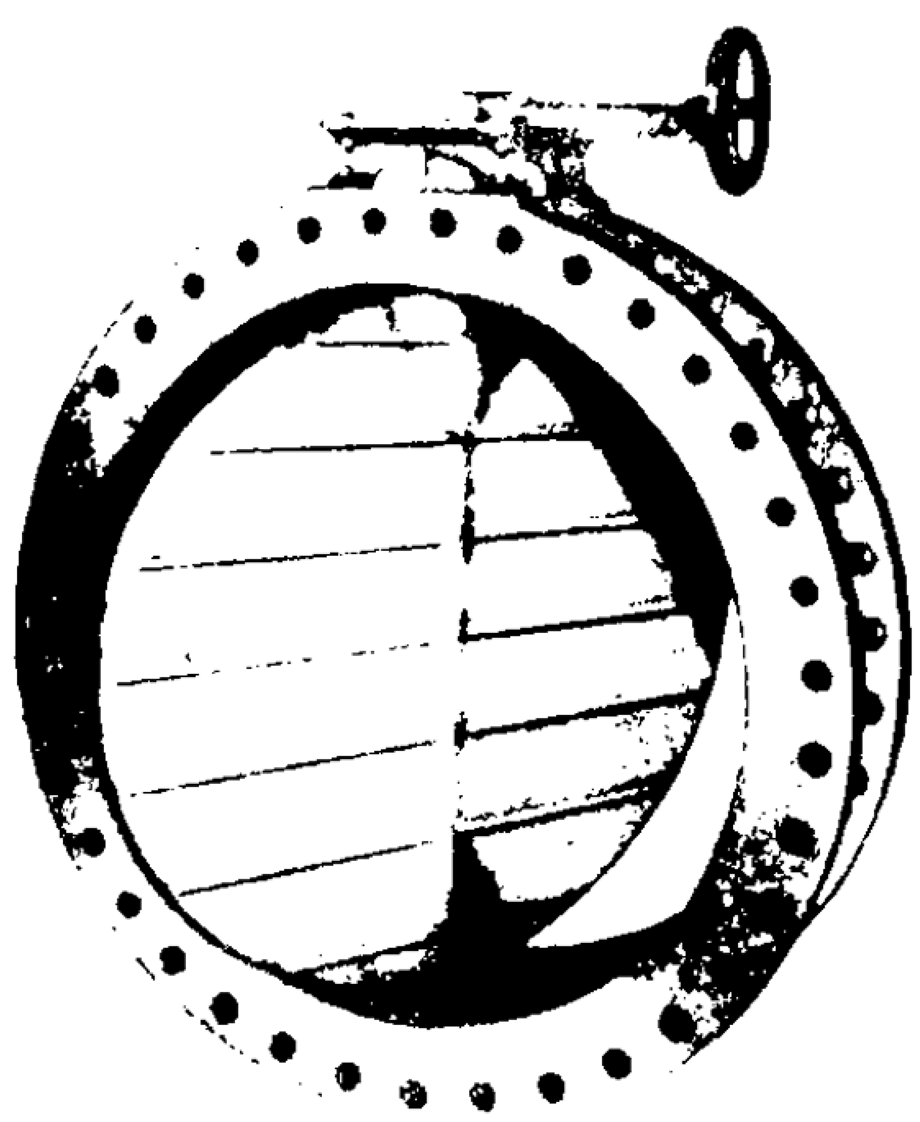


PLUG VALVE ††

LOCATION - Any place in pipe.
USE - To control flow of fluid. For lines carrying sediment.
NOTES - This valve comes in a variety of combinations including straightway, 3 way - 2 port (illus.), 3 way - 3 port, and 4 way - 2 port.

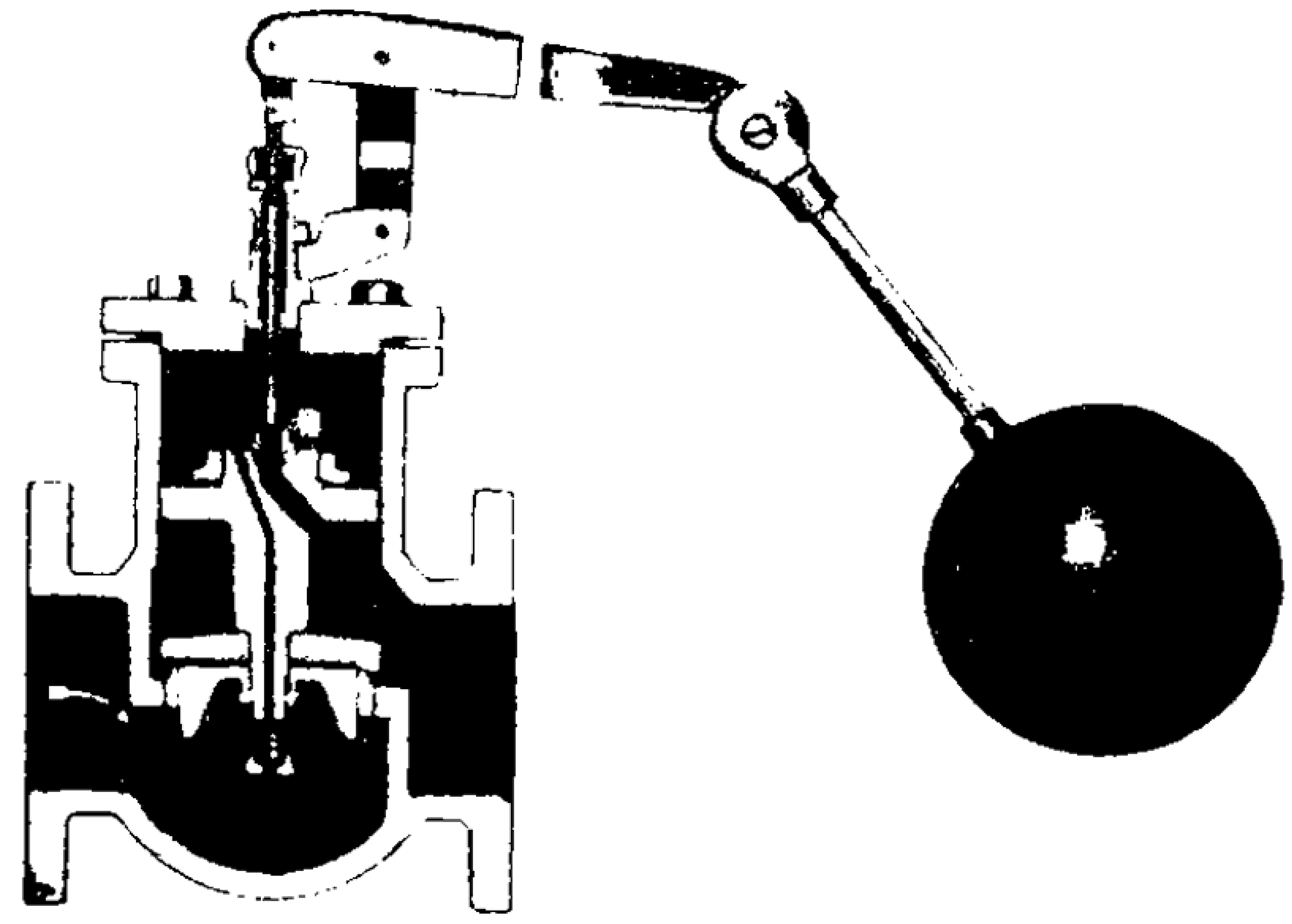
SLIDE OR SLUICE GATES **

LOCATION - At ends of pipe or channel.
USE - To control discharge at relatively low pressures.
NOTE - Gate is frequently rectangular in shape.



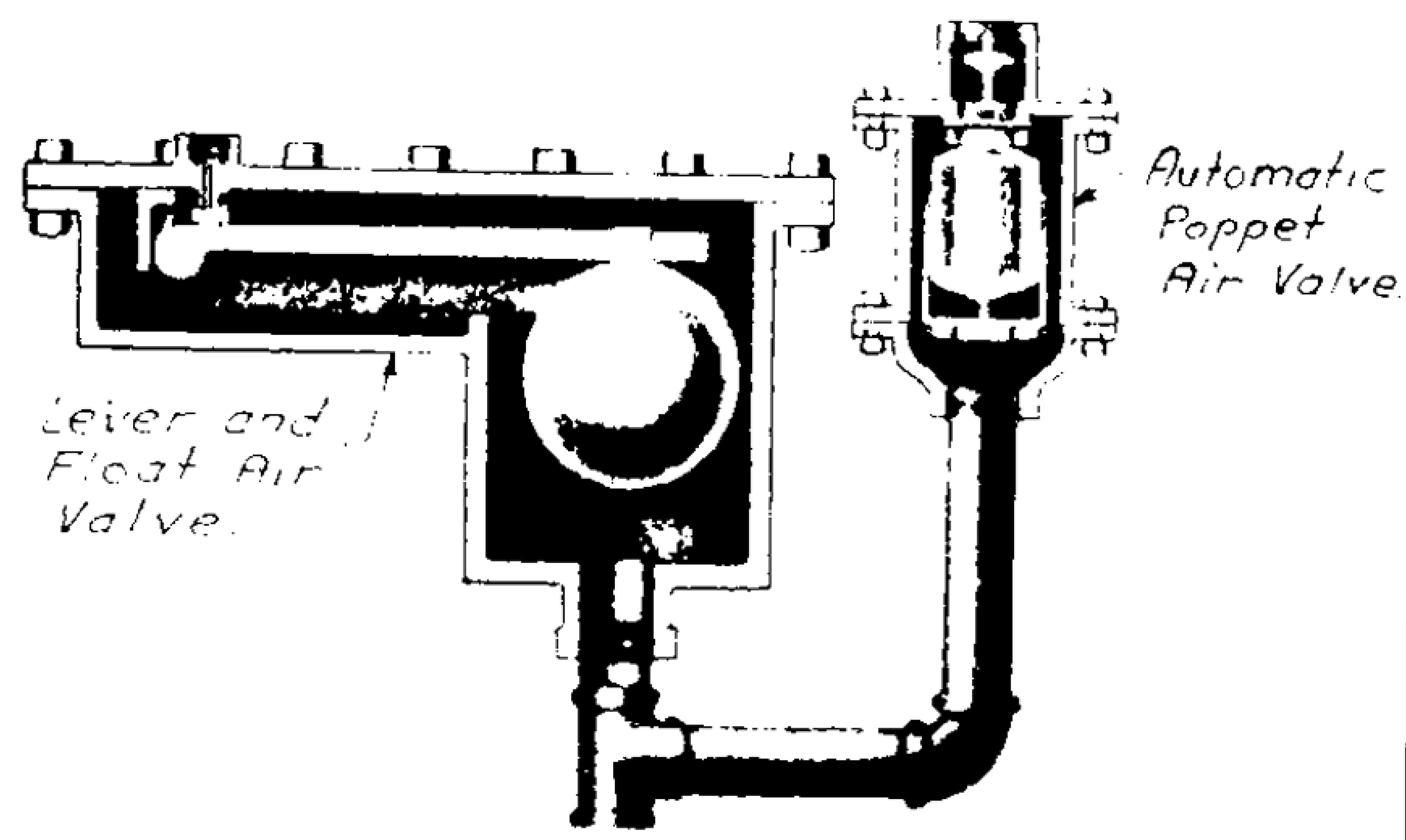
BUTTERFLY VALVE †

LOCATION - Any place in pipe.
USE - To regulate rate of flow of fluid with smaller losses than globe valve.



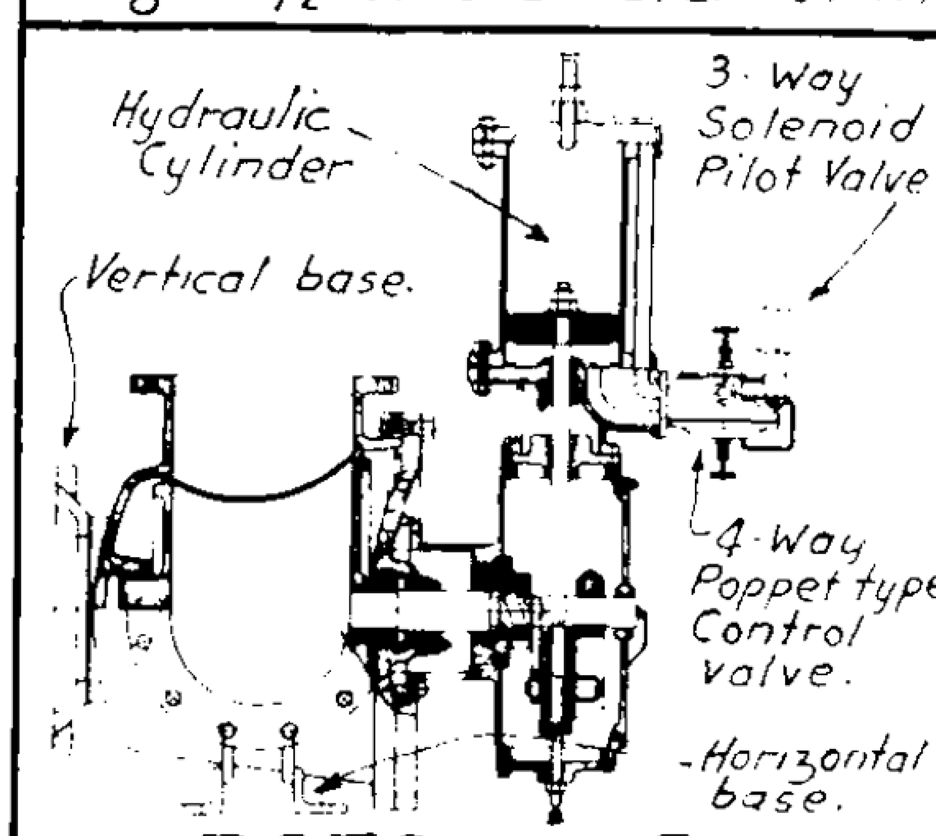
FLOAT VALVE ****

LOCATION - On supply lines to tanks or reservoirs.
USE - To control the elevation of fluid in tank or reservoir.



AUTOMATIC FLOAT & POPPET AIR VALVE *

LOCATION - At summits of pipe lines.
USE - Poppet - To allow air to escape when pipe is being filled.
USE - Float - To free pipe of air collecting under pressure when air is carried in the water. To allow air to enter steel pipes rapidly to prevent the formation of a vacuum causing a collapsing pressure in the event of a break in the steel pipe.
NOTE - Generally diameter of valve pipe is from $\frac{1}{8}$ to $\frac{1}{2}$ of diameter of main pipe.

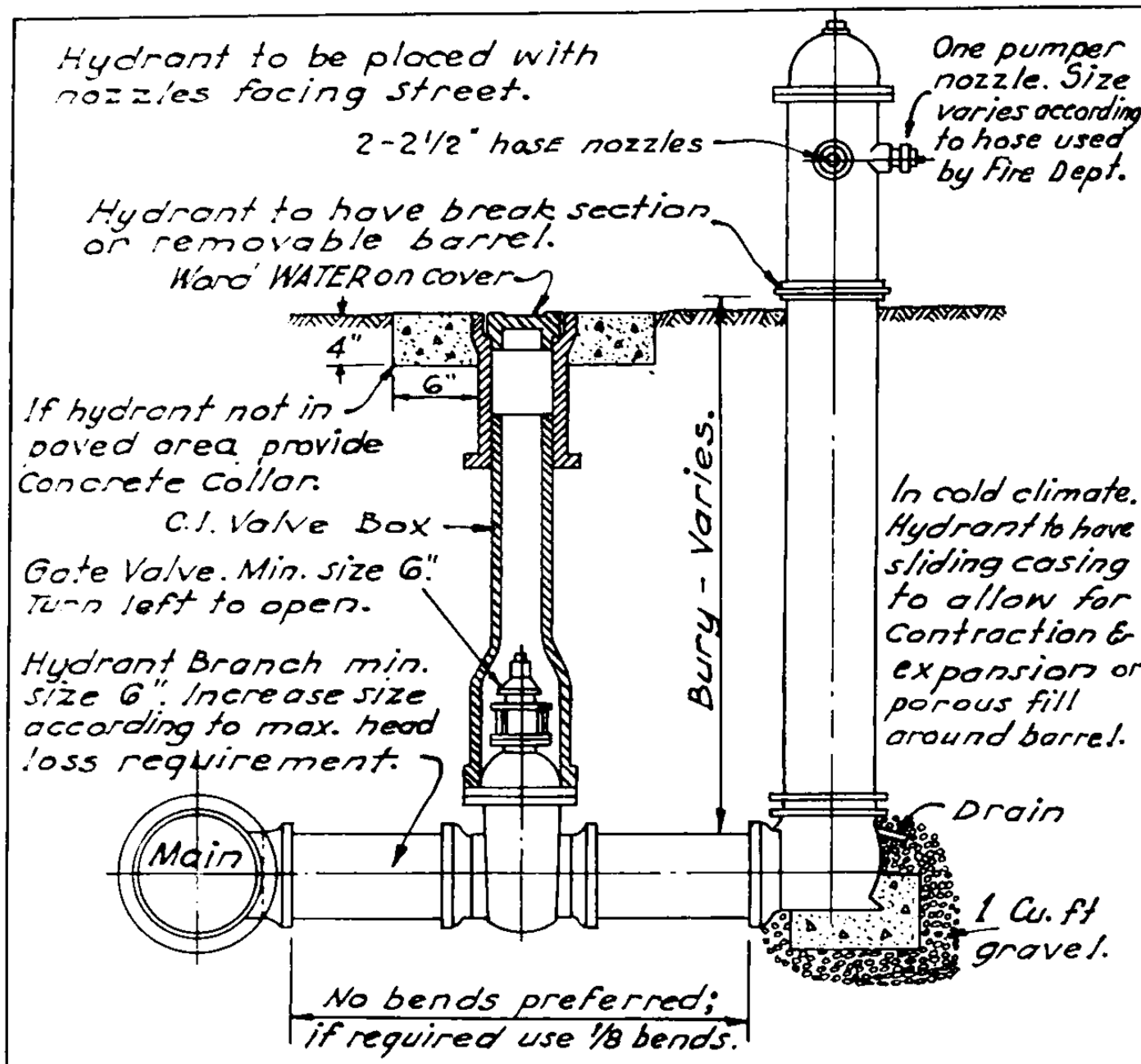


LOCATION - At pump.
USE - The solenoid control is tied in electrically with pump motor starter to open valve when pump is started and close when pump starter is tripped out. In addition valve will close on any power failure.

ROTO CHECK VALVE †††

* From Eddy Valve Co. ** From Hardesty Division, Armco Drainage and Metal Products Inc. *** From James B. Clow & Sons. † From R-S Products Corp. **** From Kiele & Mueller Inc. †† From American Car And Foundry Co. ††† From Morgan Smith Co.

WATER DISTRIBUTION-HYDRANT, SERVICE VALVE, PITOMETER



Maximum head loss 5 lbs. between main and hydrant outlet.

For hydrant spacing See Table A-Pg. 6-01 & Fig. A-Pg. 6-60.

FIG. A - HYDRANT DETAIL.*

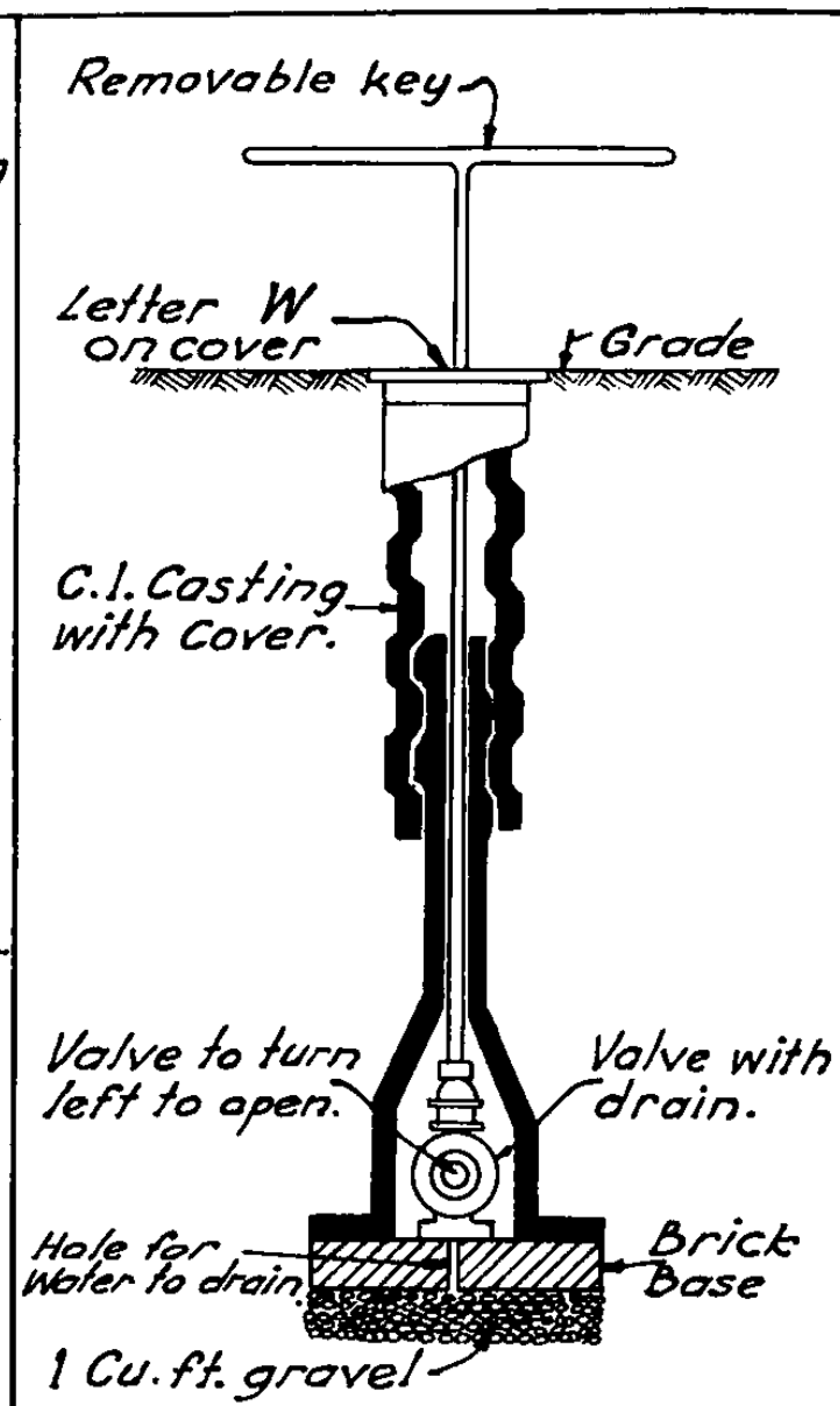


FIG. B-HOUSE SERVICE VALVE & BOX.

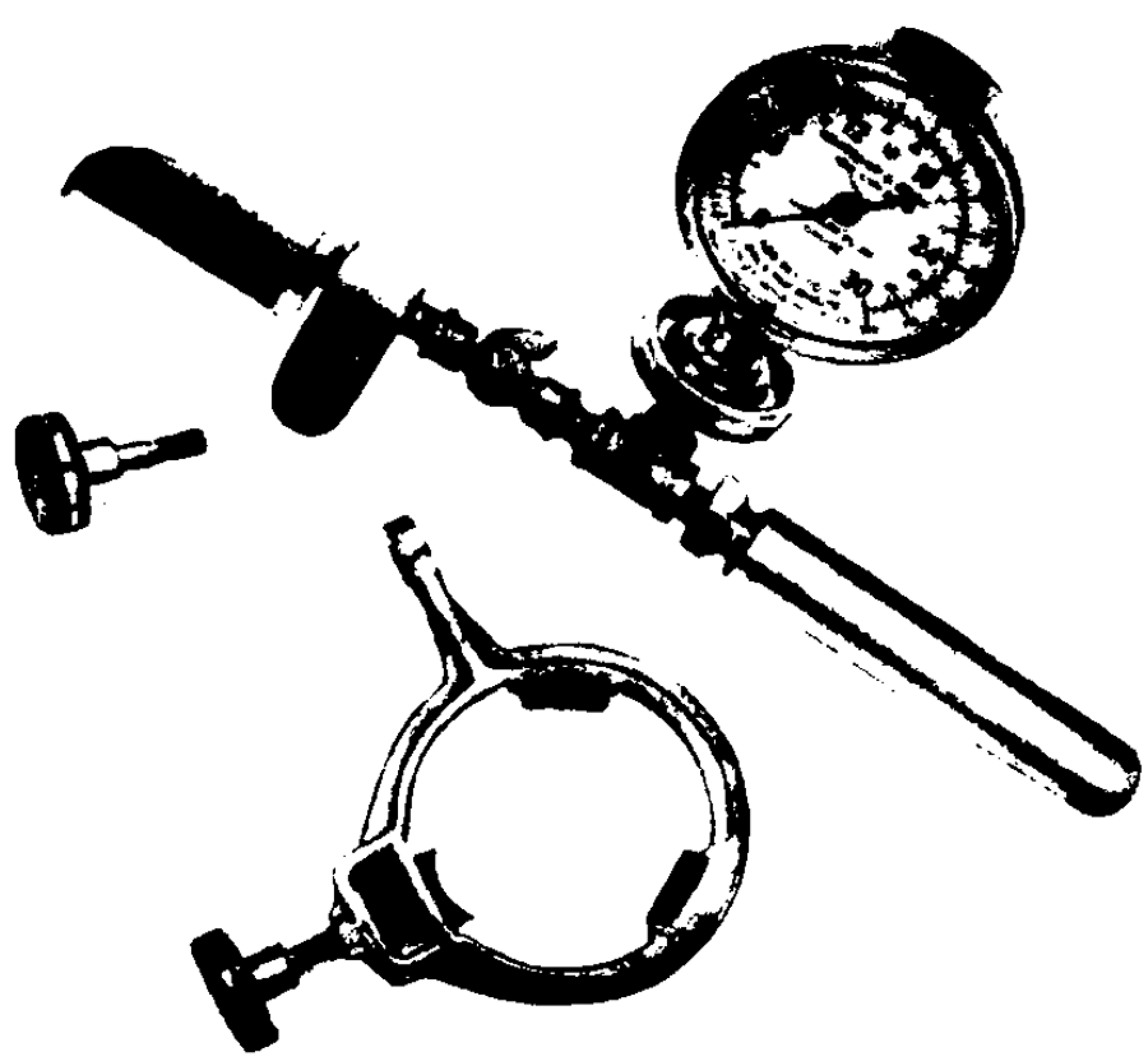
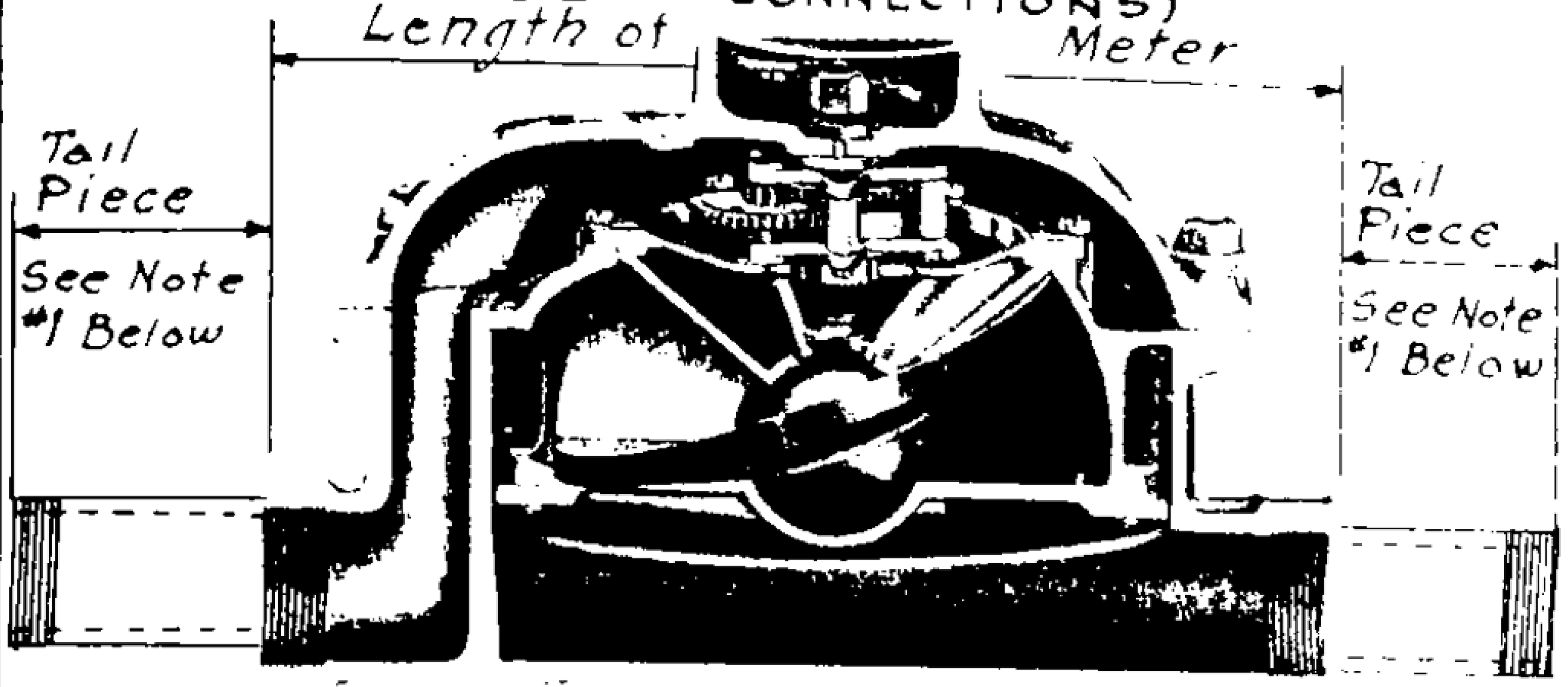


FIG. C-COMBINATION HAND AND CLAMP PITOMETER FOR HYDRANT FLOW TESTS.**

* See Hydrant Manufacturers' Catalogs.
** From Northrop & Company, Inc.

WATER DISTRIBUTION - METERS - 1

SERVICE METERS
(HOUSE CONNECTIONS)



DISK DISPLACEMENT TYPE METER *

TABLE A- COLD WATER METERS DISPLACEMENT TYPE A.W.W.A. SPECS**

METER SIZE	SAFE MAXIMUM OPERATING CAPACITY	MAXIMUM LOSS OF HEAD	MINIMUM TEST FLOW	NORMAL TEST FLOW	METER LENGTH SCREW ENDS	METER LENGTH FLANGE ENDS	RECOMMENDED NUMBER OF YEARS BETWEEN TESTS
(1) INCHES	(2) G.P.M.	(3) LBS. PER SQ. INCH	(4) G.P.M.	(5) G.P.M.	(6) INCHES	(7) INCHES	(8) YEARS
$\frac{5}{8}$	20	15	$\frac{1}{4}$	1 to 20	$7\frac{1}{2}$	-	10
$\frac{3}{4}$	30	15	$\frac{1}{2}$	2 to 30	9	-	8
1	50	15	$\frac{3}{4}$	3 to 50	$10\frac{3}{4}$	-	6
$1\frac{1}{2}$	100	20	$1\frac{1}{2}$	5 to 100	$12\frac{5}{8}$	13	4
2	160	20	2	8 to 160	$15\frac{1}{4}$	17	4
3	300	20	4	16 to 300	-	24	3
4	500	20	7	28 to 500	-	29	2
6	1000	20	12	48 to 1000	-	$36\frac{1}{2}$	1

NOTES:-
1. Coupling tail piece lengths: $\frac{5}{8}$" size = $2\frac{3}{8}$", $\frac{3}{4}$" size = $2\frac{1}{2}$", 1" size = $2\frac{5}{8}$" long.
2. Accuracy of registration should be ±1.5% when tested within the limits listed in column #5 (Normal Test Flow) with water having a temperature less than 80°F. Tested at Minimum Test Flow (column #4), meter shall not record less than 95% of the actual flow through it.
3. The capacities of the meters given in column #2 are the maximum rates of flow at which water should be passed through meters for short periods of time or the peak loads which should come upon meters only at long intervals. For continuous 24-hour service, meters of the displacement type should not be operated on flows greater than one-fifth ($\frac{1}{5}$) of the capacity of the meter.

MAIN LINE METERS
(VELOCITY TYPE)

TYPES OF METERS COMMONLY USED

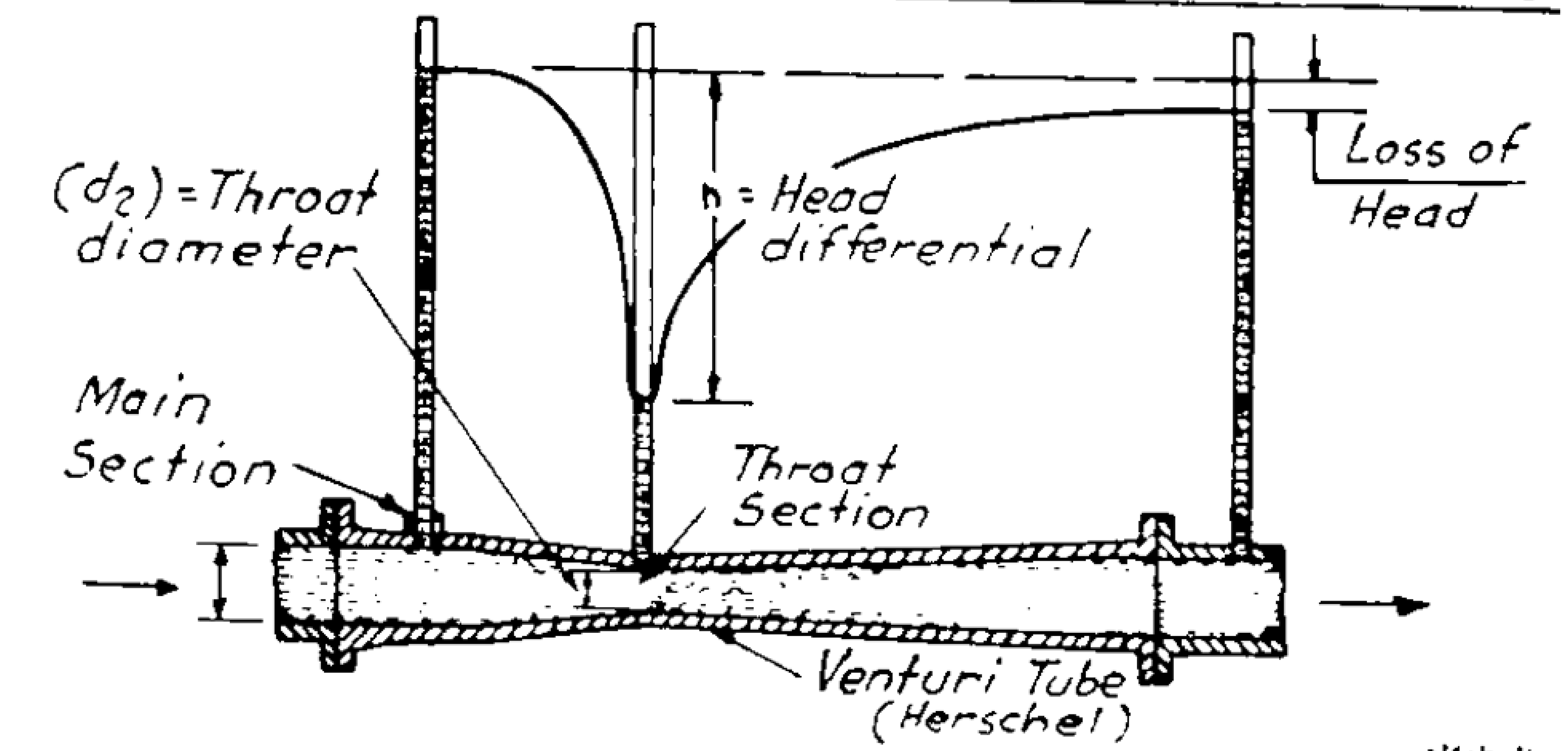


FIG. B-STANDARD VENTURI SECTION.***

NOTE:- Occasionally a special short Venturi tube (S4) is used.

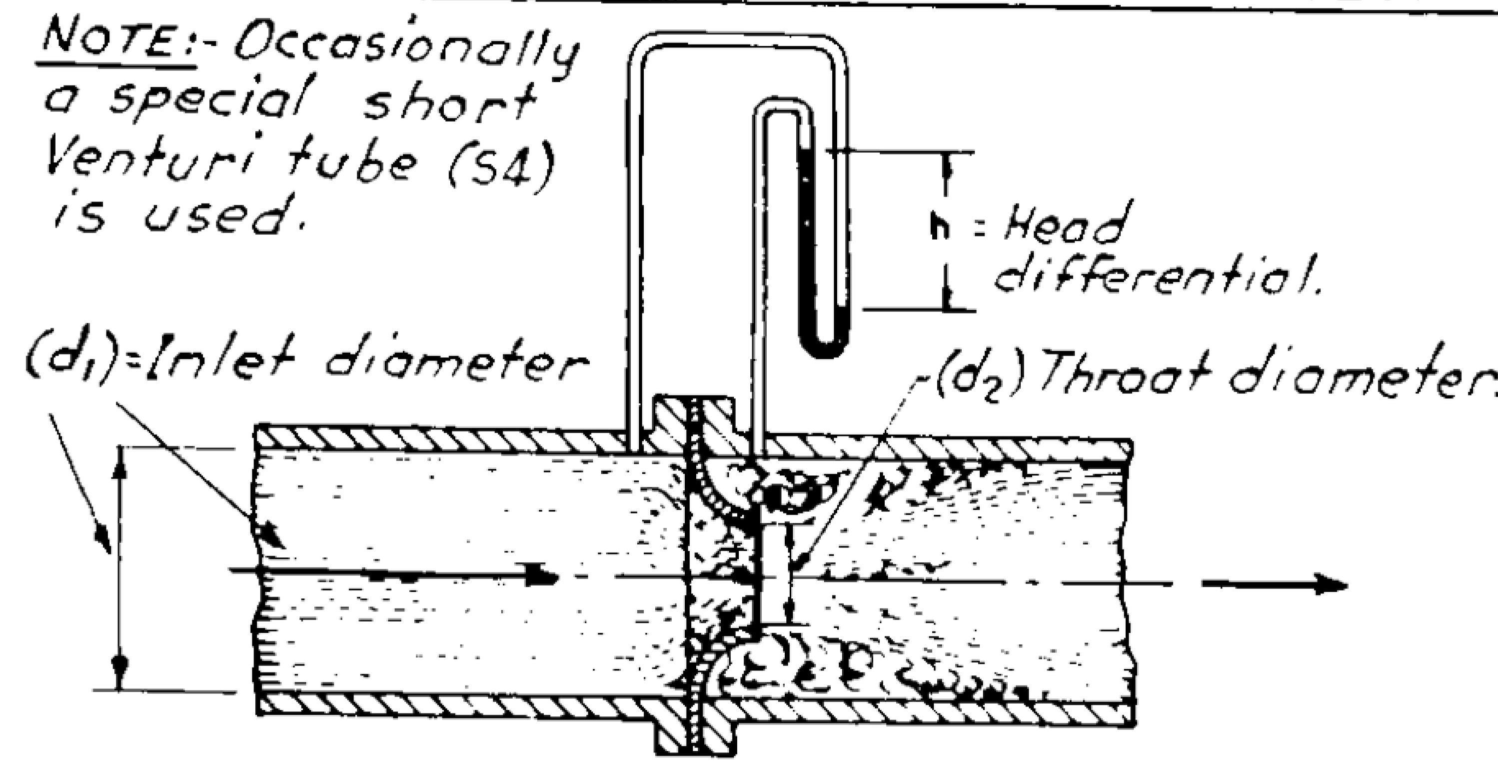


FIG. C-FLOW NOZZLE.***

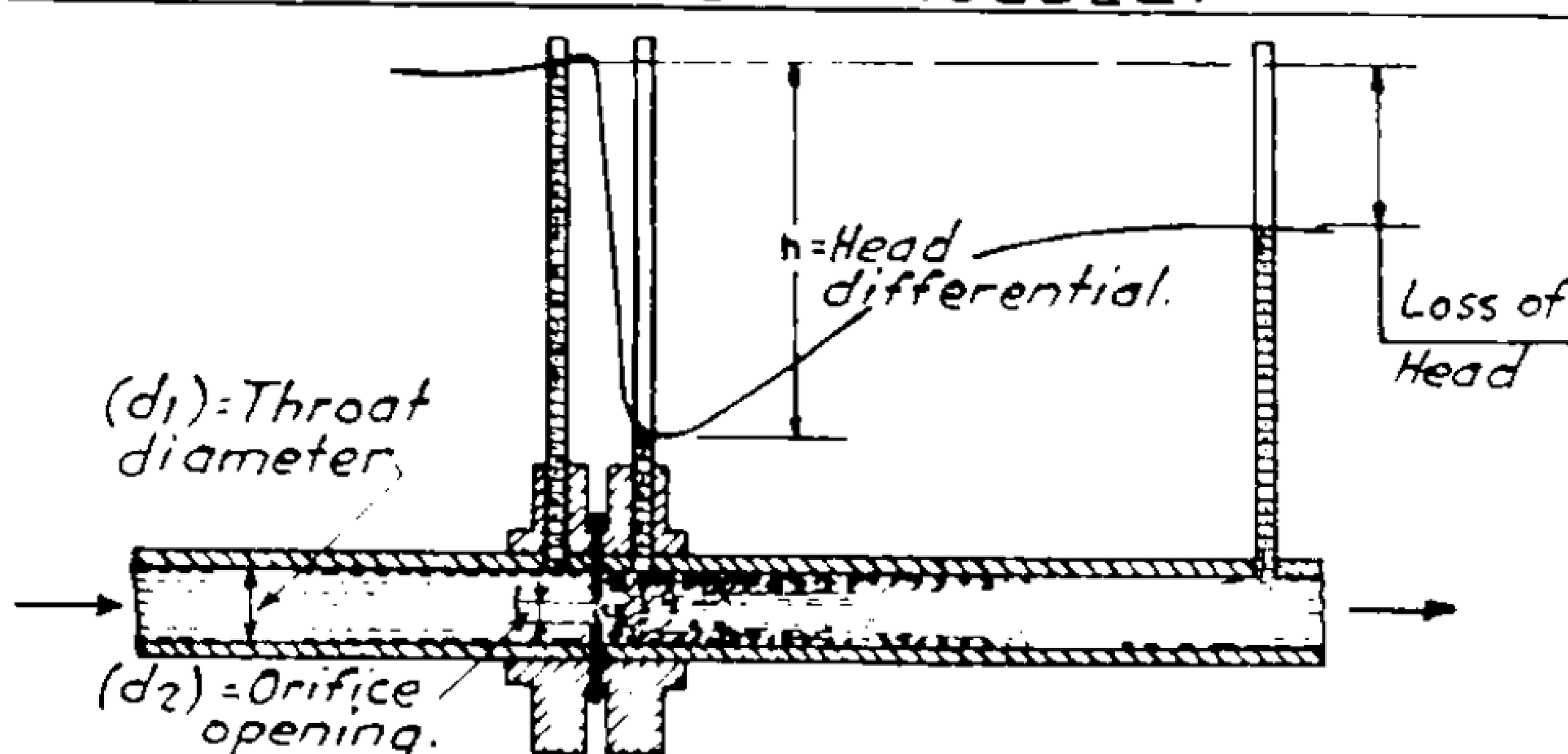


FIG. D-FLAT PLATE ORIFICE - FLANGE TYPE.***

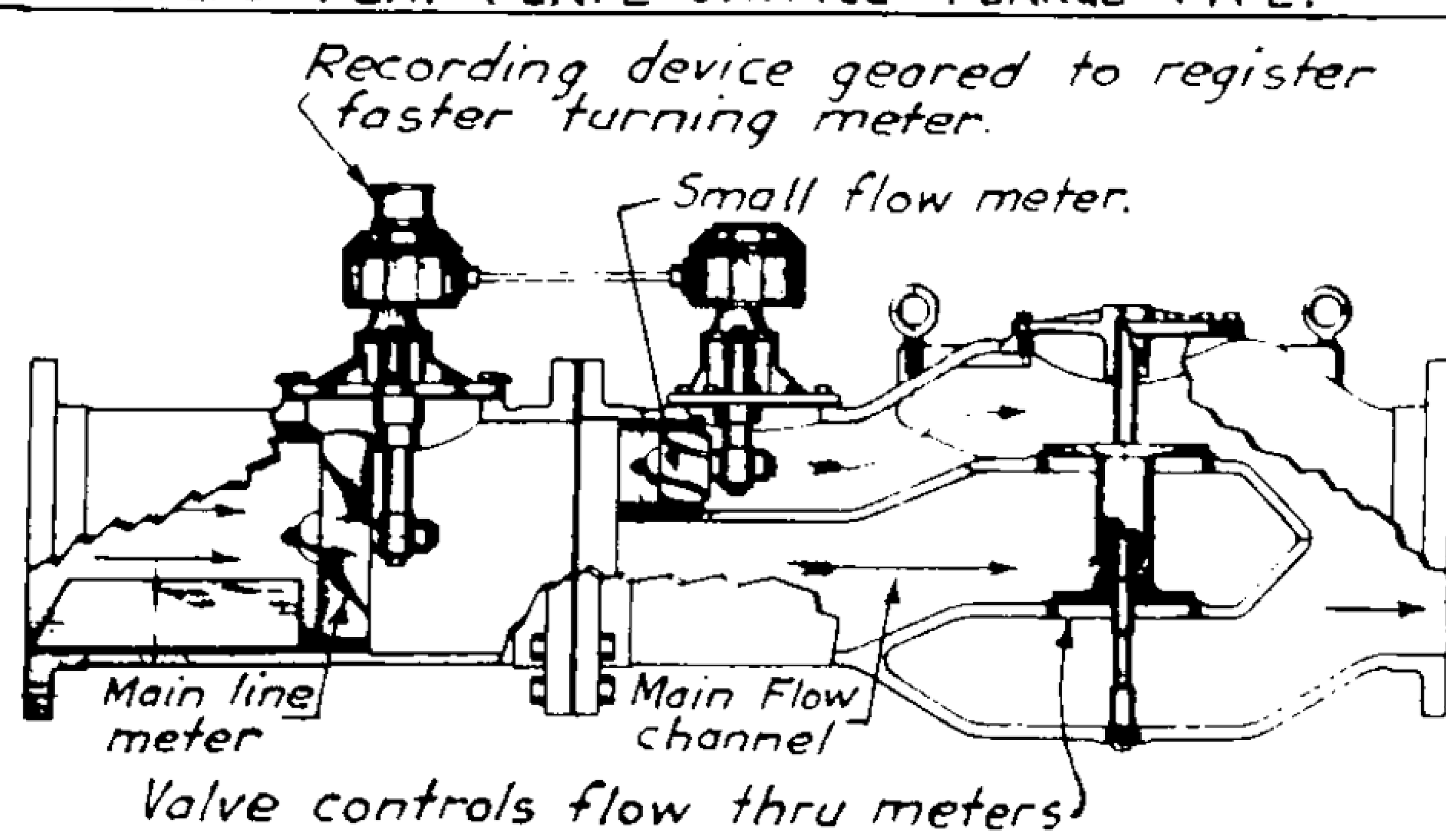


FIG. E-COMPOUND METER. †

Note For All Meters - It is generally better to select a slightly undersized meter rather than one slightly oversized as better accuracy will usually be obtained.

* Adapted from Hersey Mfg. Co.

† From R.W. Sparling Bulletin 307, 1941

** From American Water Works Association Tentative Specifications 7M.1-T Nov. 1941.

*** From Water Works and Sewerage, June 1943, "Selection of Main Line Meters," J. C. Thoresen, Builders Providence, Inc., Prov. R. I.

WATER DISTRIBUTION - METERS-2

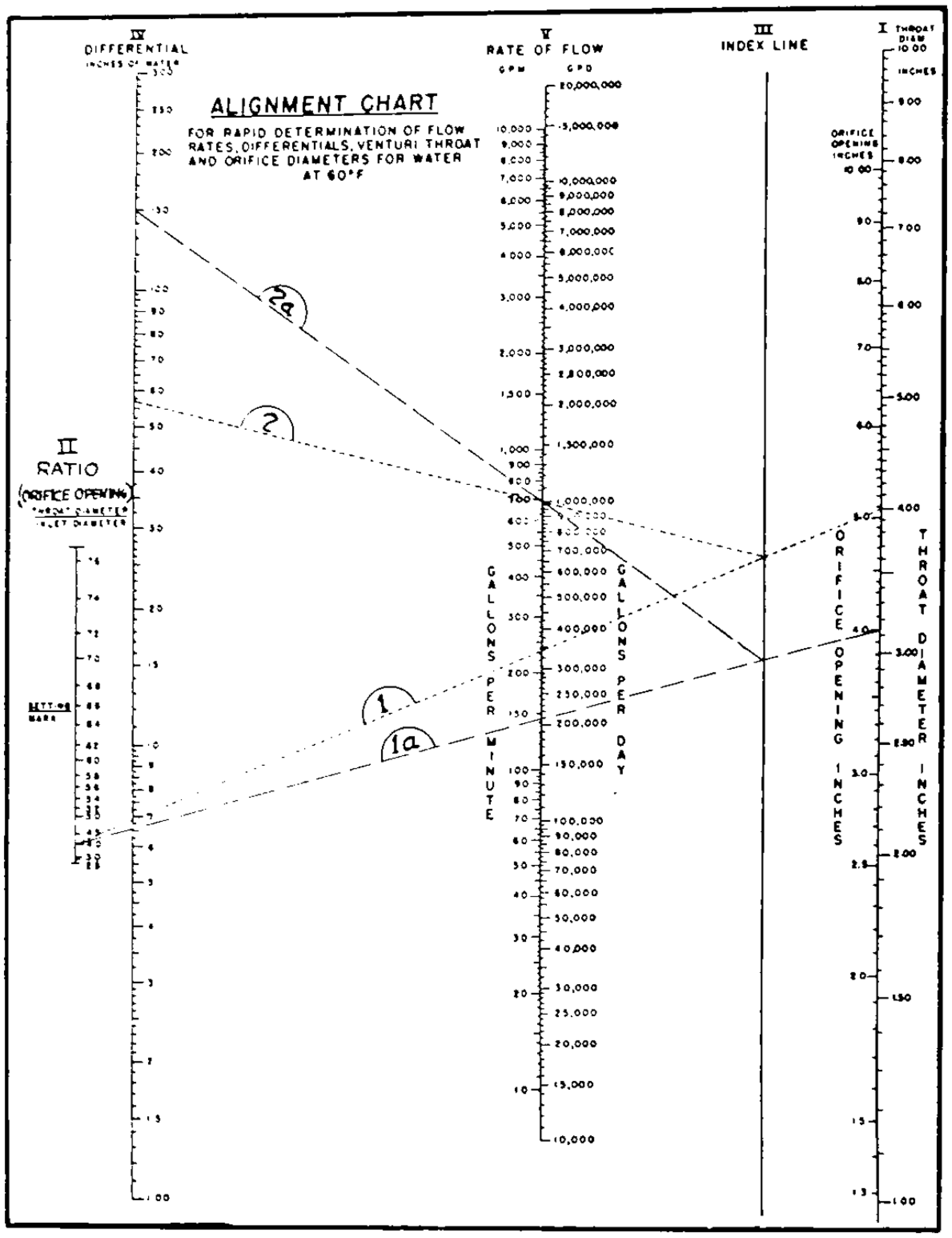


FIG. A- FLOW RATES & DIFFERENTIALS FOR STANDARD VENTURI THROAT & ORIFICE DIAMETERS.*

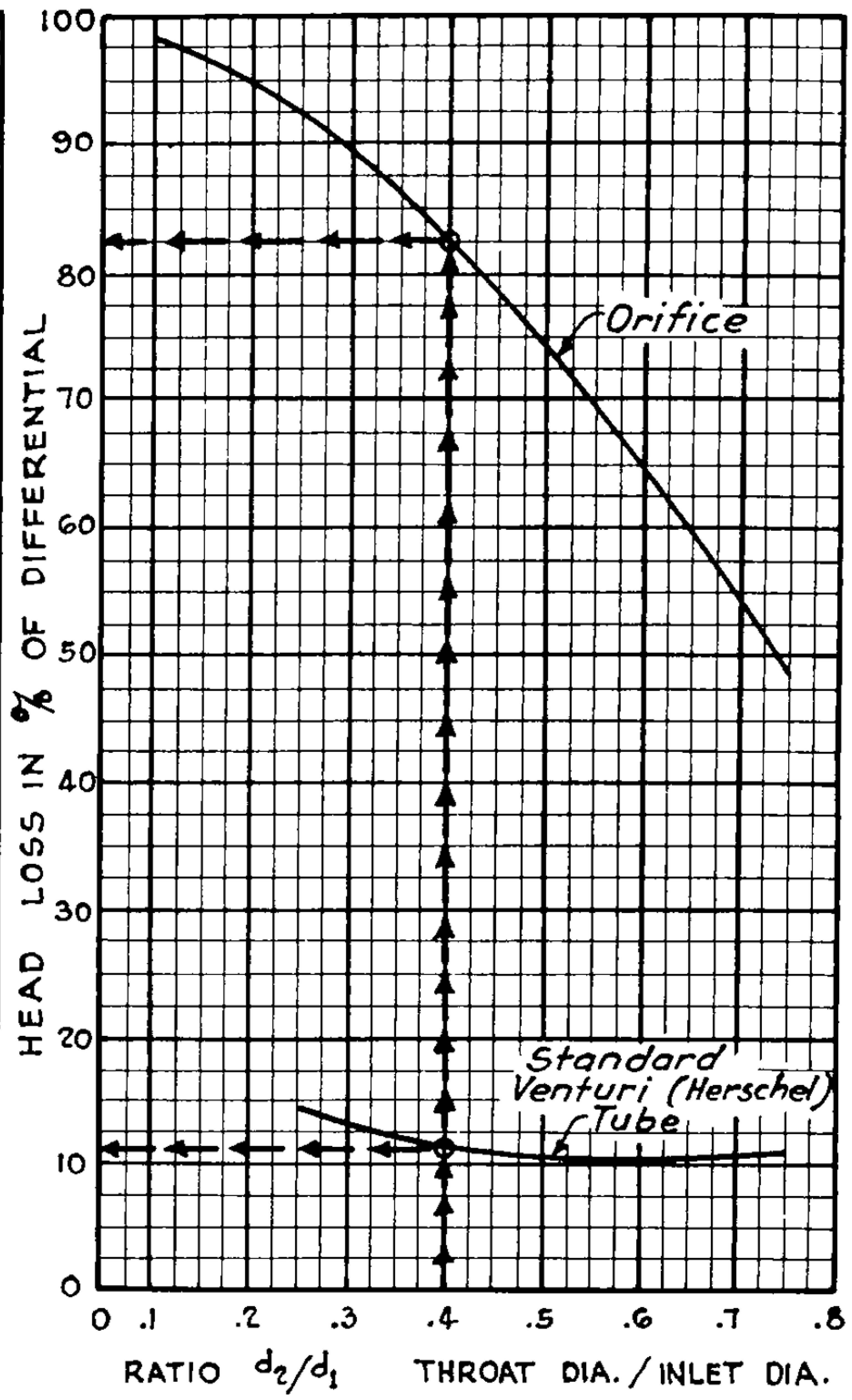


FIG. B- HEAD LOSS IN STANDARD VENTURI TUBE AND ORIFICE.

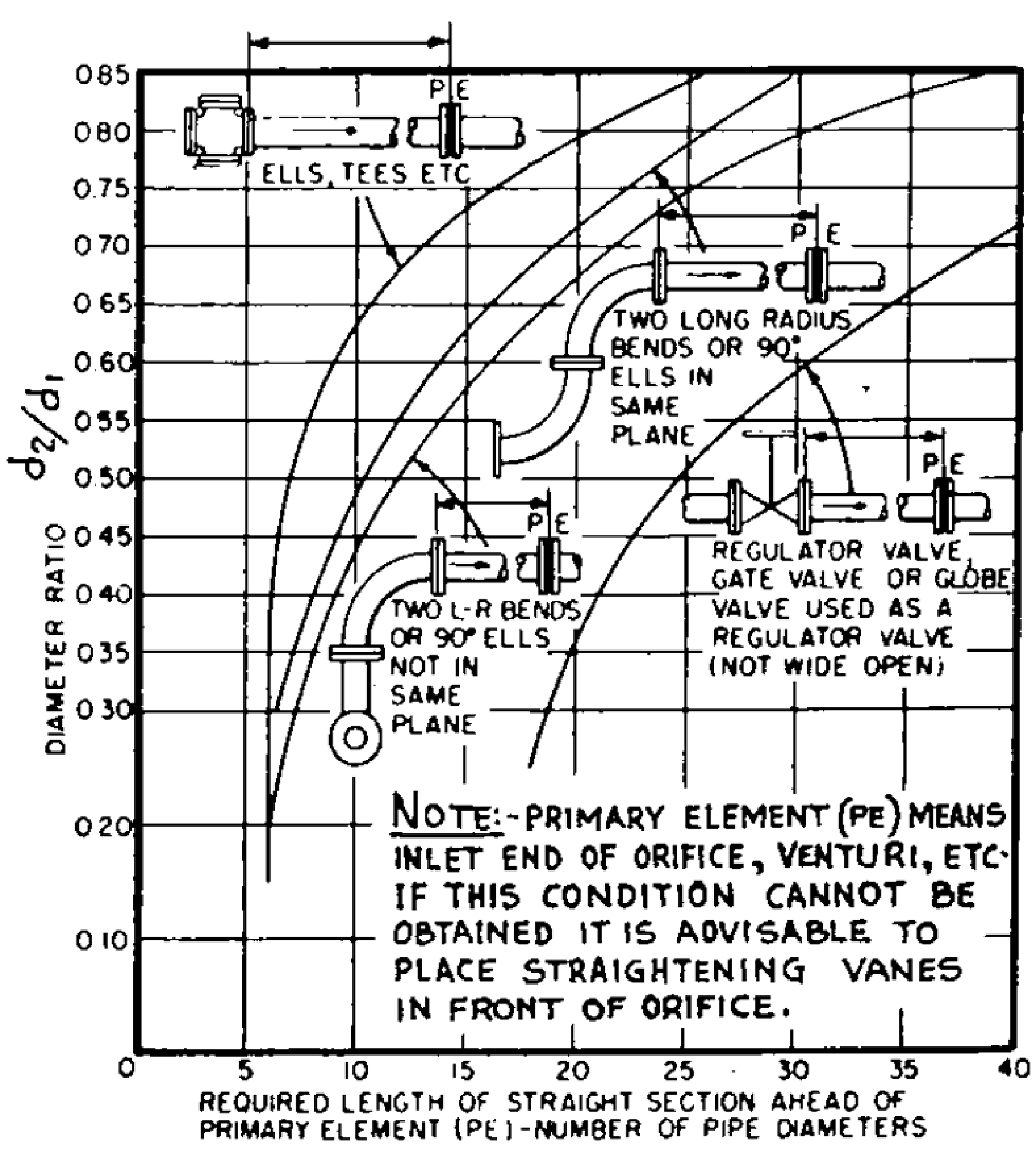
EXAMPLE OF THE USE OF FIGURES A & B.

Given- Inlet diameter - d_1 = 10.00 inches.
Throat diameter or orifice opening - d_2 = 4.00 inches.
Rate of flow = 1,000,000 gallons per day (G.P.D.).

Required - 1. Head differential - h betw. inlet and throat when
a - Standard Venturi tube is used.
b - Orifice is used.
2. Loss of head in each case.

Example - Ratio of throat dia. or orifice opening to Inlet dia. $d_2/d_1 = 0.4$.
In Fig. A set straight edge at 4.00 inches in col. I and 0.4 in col. II and mark intersections with col. III (lines 1 and 1a).
Set straight edge at intersections on col. III and 1,000,000 G.P.D. col. V (lines 2 and 2a) and read differentials on col. IV of 57 inches for Venturi tube and 150 inches for orifice.
From arrow lines in Fig. B a. Venturi tube loss = 0.11 × 57 = 6.27 inches.
b. Orifice loss = 0.82 × 150 = 123 inches.

* From Water Works and Sewerage, June 1943, "Selection of Main Line Meters," J. C. Thoresen, Builders Providence, Inc., Prov. R.I.



METER LOCATION

From Bailey Meter Co. Bulletin 301A.

WATER DISTRIBUTION - METERS - 3

CAPACITIES OF VENTURI TUBES * (SEE FIG. B ON PAGE 6-81).

Size of Tube Inches	Length Feet & Inches	Capacity in Gallons per Day Maximum	Capacity in Gallons per Day Minimum	Size of Tube Inches	Length Feet & Inches	Capacity in Gallons per Day Maximum	Capacity in Gallons per Day Minimum
2 x 25/32 †	15 13/32"	53,000	2,600	18 x 9	7' - 2 1/4"	7,196,000	360,000
2 x 27/32	15 13/32"	62,200	3,100	18 x 11	6' - 2 1/8"	11,220,000	561,000
2 x 1	14 1/16"	89,000	4,500	20 x 8	8' - 11"	5,600,000	280,000
4 x 1 3/4	2' - 4"	270,000	13,500	20 x 10	7' - 10 7/8"	8,900,000	445,000
4 x 2	2' - 1 1/8"	355,000	17,700	20 x 12	6' - 10 11/16"	13,200,000	665,000
4 x 2 3/8	23 3/4"	519,000	26,000	20 x 13	6' - 4 7/8"	16,040,000	802,000
6 x 2 1/2	3' - 0 9/16"	546,000	27,300	24 x 8	11' - 4 5/16"	5,540,000	277,000
6 x 3	2' - 9 1/4"	800,000	40,000	24 x 11	9' - 10 1/8"	10,600,000	530,000
6 x 3 1/2	2' - 5 7/16"	1,120,000	56,000	24 x 12	9' - 4"	12,760,000	638,000
6 x 3 63/64	2' - 3 1/8"	1,520,000	76,000	24 x 14	8' x 3 1/8"	17,930,000	896,000
8 x 3	3' - 11 7/16"	782,000	39,000	24 x 16	7' 3 11/16"	24,580,000	1,230,000
8 x 4	3' - 5 5/8"	1,418,000	71,000	30 x 12	13' - 0 1/16"	12,550,000	627,000
8 x 5	2' - 11 1/4"	2,336,000	117,000	30 x 15	11' - 5 3/4"	20,000,000	1,000,000
10 x 4	4' - 7 1/2"	1,394,000	69,500	30 x 16 1/2	10' 8 5/8"	24,600,000	1 230,000
10 x 5	4' - 1 3/8"	2,220,000	111,000	30 x 18	9' - 11 1/2"	30,000,000	1,500,000
10 x 6	3' - 7 3/8"	3,320,000	166,000	36 x 15	15' - 1 3/4"	19,700,000	985,000
12 x 4	5' - 9 13/16"	1,385,000	69,000	36 x 18	13' - 7 5/16"	28,750,000	1,440,000
12 x 5	5' - 3 5/8"	2,184,000	109,000	36 x 20	12' - 7 3/8"	36,000,000	1,800,000
12 x 6	4' - 9 5/16"	3,198,000	160,000	36 x 22	11' - 7 3/16"	45,000,000	2,250,000
12 x 7	4' - 3 3/8"	4,480,000	224,000	42 x 21	16' - 0 1/4"	39,200,000	1,960,000
12 x 8	3' - 9 9/16"	6,145,000	307,000	42 x 22	15' - 6 5/16"	43,300,000	2,165,000
14 x 6	6' - 0 3/16"	3,150,000	157,500	42 x 24	14' - 6"	52,420,000	2,621,000
14 x 7	5' - 6 1/8"	4,350,000	217,000	48 x 20	20' - 2 1/2"	35,000,000	1,750,000
14 x 8	5' - 0 1/16"	5,820,000	291,000	48 x 24	18' - 2"	51,000,000	2,550,000
14 x 9	4' - 5 15/16"	7,651,000	380,000	48 x 28	16' - 1 11/16"	72,000,000	3,600,000
16 x 6	7' - 2 7/8"	3,127,000	156,500	54 x 24	21' - 10"	50,500,000	2,500,000
16 x 7	6' - 8 3/4"	4,295,000	214,000	54 x 30	18' - 9 9/16"	82,000,000	4,100,000
16 x 8	6' - 2 11/16"	5,685,000	284,000	54 x 38	15' - 3 7/8"	144,000,000	7,200,000
16 x 9	5' - 8 5/8"	7,344,000	368,000	60 x 24	25' - 6 1/8"	50,200,000	2,510,000
16 x 9 1/2	5' - 5 9/16"	8,295,000	415,000	60 x 30	22' - 5 1/2"	80,000,000	4,000,000
18 x 7	8' - 2 7/16"	4,264,000	213,000	60 x 36	19' - 5"	119,500,000	5,975,000

NOTES:-

1. The table to the left is a partial list of Standard Venturi Tubes made by the Simplex Valve & Meter Co. These meter sizes and others can be furnished by various manufacturers.
2. The lengths given in the table are for tubes having bell or flanged ends. For spigot ends approx. 6" to 12" has to be added.
3. The flow range (ratio of maximum capacity to minimum capacity) of Simplex meters is 20:1. Other manufacturers make Venturi Tubes that have flow ranges of 10:1 and 15:1.

† 2" is diameter of main pipe $\frac{25}{32}$" is diameter of throat.

CAPACITIES OF COMPOUND METERS ** (SEE FIG. E ON PAGE 6-81).

SIZE INCHES	NORMAL RANGE GALS. PER MINUTE	OVERALL LENGTH INCHES FLANGED ENDS	OVERALL LENGTH INCHES BELL & SPIGOT ENDS
6 - 2 ††	15-900	52	57 1/2
8 - 3	30-1200	58	66 1/2
10 - 3	30-1500	68	76 1/2
12 - 4	45-2000	70 1/2	79
14 - 4	45-2500	96	105
16 - 4	45-3500	102	110 1/2
18 - 5	75-4500	114	122
20 - 5	75-5500	120	128 1/2
24 - 6	90-8000	132	140 1/2
30 - 8	100-12000	159	168 1/2
36 - 10	125-16000	171	180 1/2

NOTES:-

1. The table to the left is a list of the compound meters manufactured by R.W. Sparling. Various other companies supply compound meters having the same and different capacities and sizes.

†† 6" is diameter of main pipe and large measuring unit and 2" is diameter of small measuring unit.

* Courtesy of Simplex Valve & Meter Co.
** Courtesy of R.W. Sparling Co.

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